Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

JUNE, 1951

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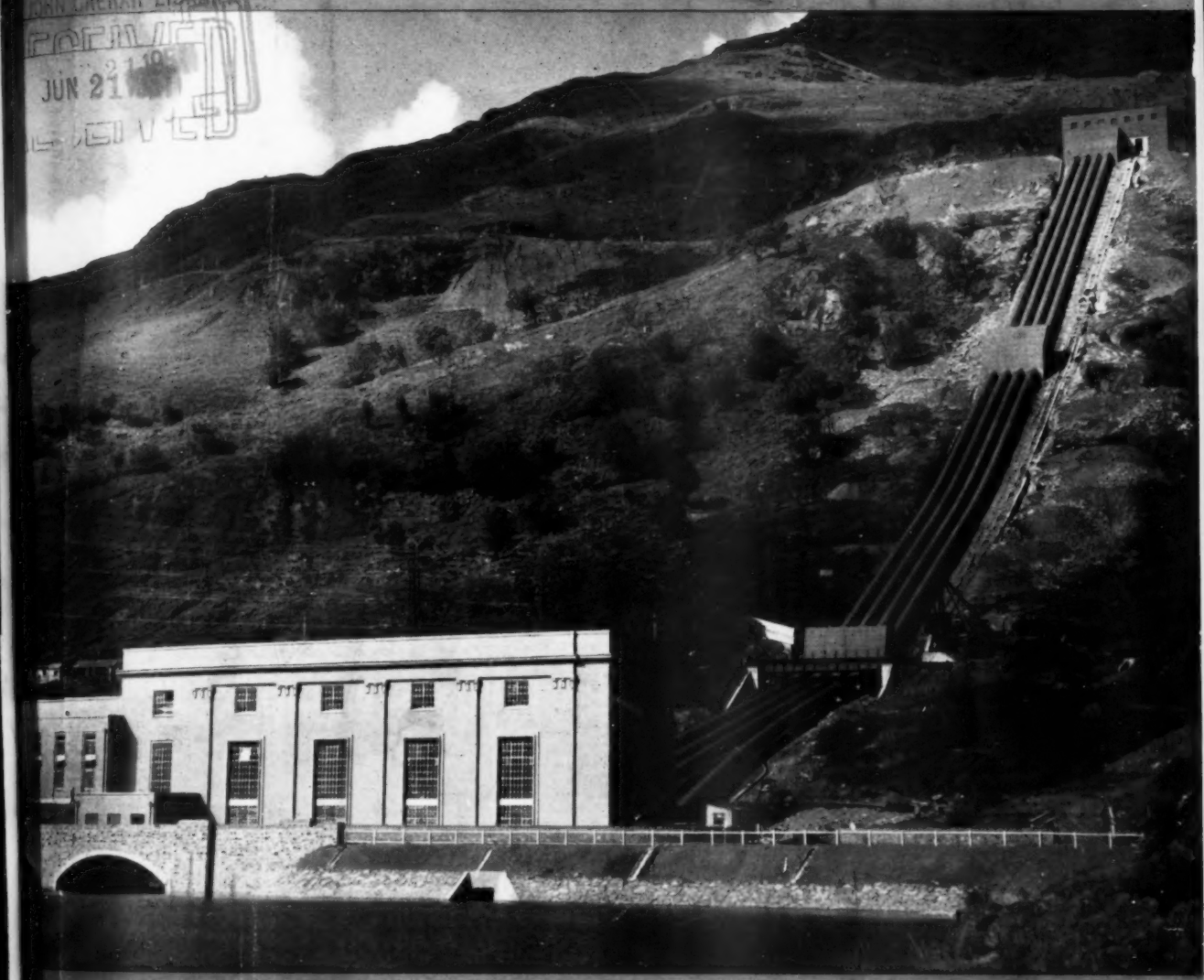


NGLISH ELECTRIC'

hydro-electric power

130 Megawatts from Sloy

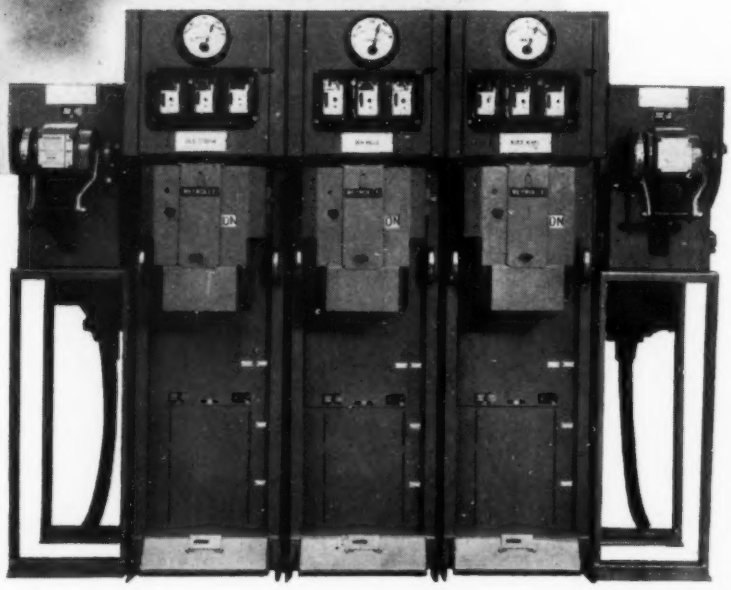
At Loch Sloy four 'English Electric' 45,500 h.p. water turbines coupled to four 32,500-kW alternators have added 130 megawatts of power to the British grid. 'English Electric', who have contributed extensively to Scotland's hydro-electric development are continually building equipment for this vast project.

The ENGLISH ELECTRIC Company Limited, Queens House, Kingsway, London, W.C.2

Hydraulic Department, Stafford

Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

VICTORIA FALLS
Southern Rhodesia

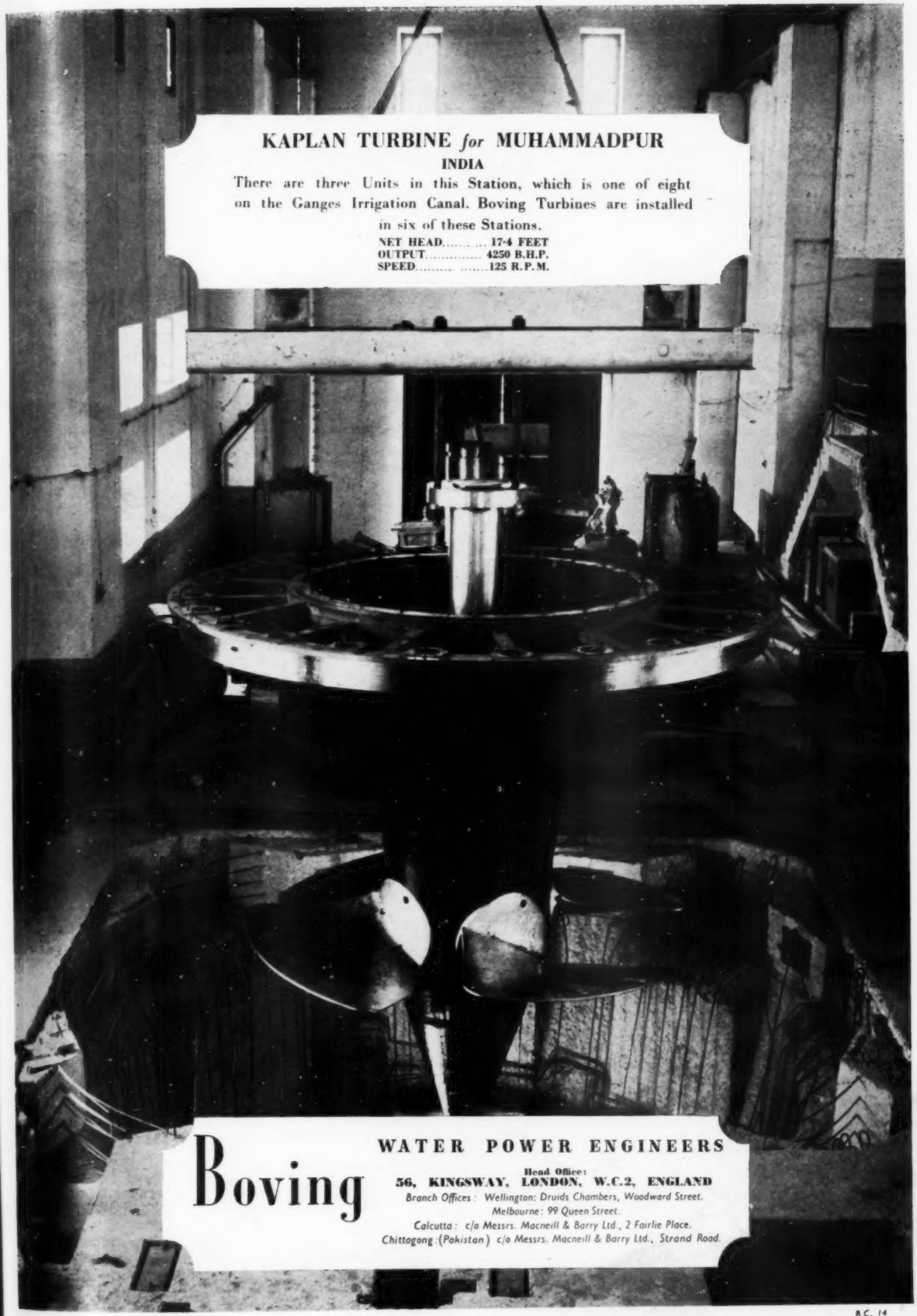


TYPE-5LA * 11,000 Volt * 150MVA * DISTRIBUTION SWITCHGEAR

One of a number
of installations
in the Municipality
of LIVINGSTONE

REYROLLE

HEBBURN * Co. DURHAM * ENGLAND


KAPLAN TURBINE for MUHAMMADPUR
INDIA
There are three Units in this Station, which is one of eight on the Ganges Irrigation Canal. Boving Turbines are installed in six of these Stations.
NET HEAD..... ... 17·4 FEET
OUTPUT..... 4250 B.H.P.
SPEED..... .....125 R.P.M.
Boving
WATER POWER ENGINEERS
Head Office:
56, KINGSWAY, LONDON, W.C.2, ENGLAND
Branch Offices: Wellington: Druids Chambers, Woodward Street.
Melbourne: 99 Queen Street.
Calcutta: c/o Messrs. Macneill & Barry Ltd., 2 Fairlie Place.
Chittagong: (Pakistan) c/o Messrs. Macneill & Barry Ltd., Strand Road.

B.C. 14

Harsprång

A view of the rapids after completion of the new dam.

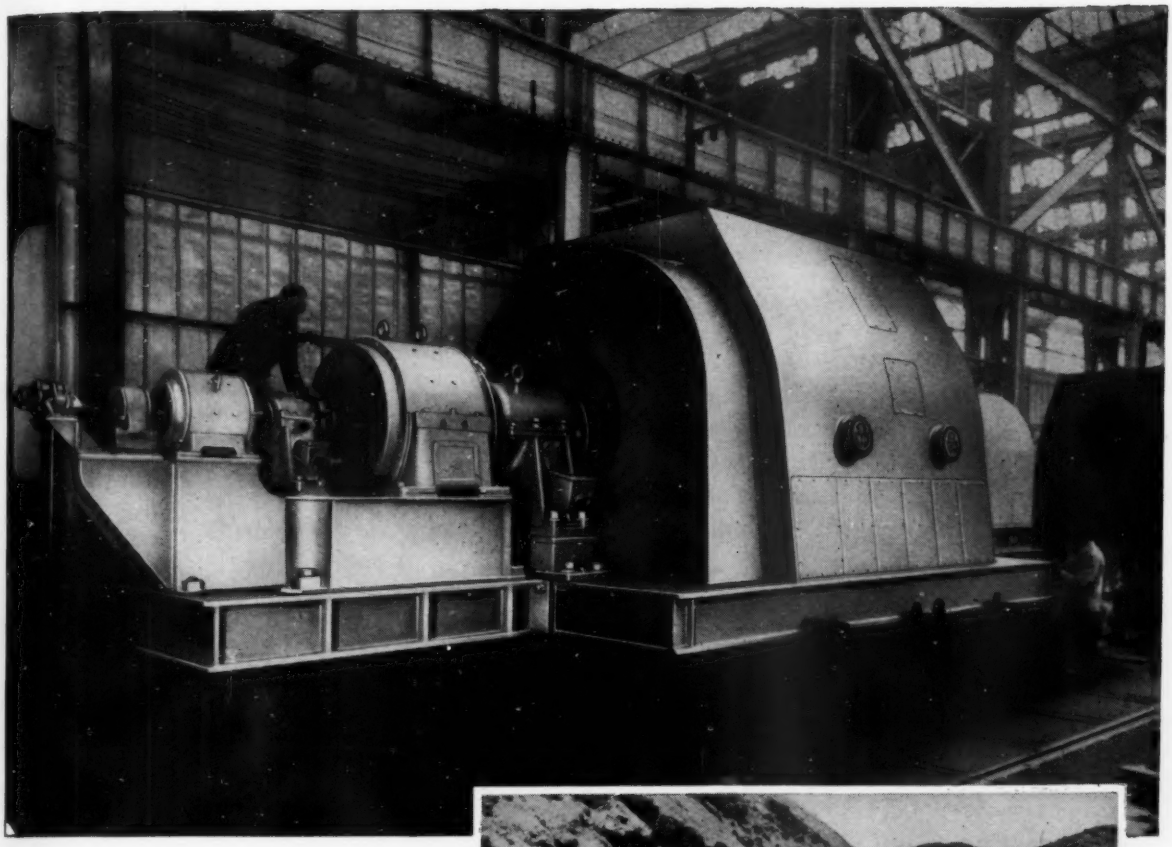
The Harsprang Power Station is situated north of the Arctic Circle and is owned by the Royal Swedish Board of Waterfalls.

Output 133,400 HP
Head 105 metres
Speed 167 r.p.m.
Water Quantity
107 cub.m/sec.

The runner for one of the Harsprang Francis turbines. Each runner is of stainless steel cast in one piece by Domnarfvet Steel Works, Sweden, and has a net weight of 35,000 Kilos.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD
KARLSTAD, SWEDEN

Hydro-electric Equipment



One of five 30,000 kVA., 750 r.p.m., 11,000 volt synchronous condensers supplied to the New Zealand State Hydro-electric Department. Two more are on order

Stator of one of the above condensers during its journey in New Zealand from the docks to site.

For all plant required for
Hydro-electric Power Schemes
— Consult BTH

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THE BRITISH THOMSON-HOUSTON CO. LTD. RUGBY, ENGLAND

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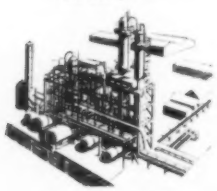
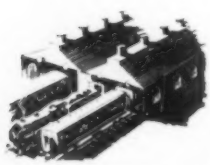


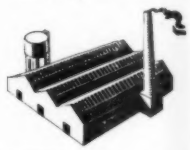
OIL REFINERIES



RAILWAY WORKSHOPS, *Rolling Mills, Printeries, Paper Mills*

ALSO IN:—

ELECTRIC GENERATING STATIONS, *Oil Pumping and Storage Installations.*



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for installations in Factories, Oil Refineries, Steel, Textile and Paper Mills, Chemical Works, etc.

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G/D48

PROOF
of LEFFEL hydraulic turbine performance

Ford Motor Company

ENGINEERING LABORATORY

DEARBORN, MICHIGAN

The James Leffel & Company
Springfield
Ohio

Attention: Mr. J. Robert Groff, President

Dear Mr. Groff:

It has been my pleasure to have worked with representatives of The Leffel Company in connection with the construction and operation of our water power plants, beginning with an installation in 1914.

As in the case of all others employing Leffel equipment, the three units at Hamilton, which were installed in 1919, have proven entirely satisfactory. The wealth of information regarding water power which The Leffel Company has compiled during its eighty-six years of existence, and which has been freely given to us, has been of inestimable value in working out problems that have arisen in connection with our water power development. In closing I would state that our experience in using the equipment and services of your company has been most satisfactory.

Very truly yours

FORD MOTOR COMPANY

C H VOORHESS

CRV:rms

The above letter of commendation from a leading American industrial organization is typical of the satisfaction which Leffel hydraulic turbines and Leffel engineering assistance arouses. The hydro-electric installations pictured above are some of those of the Ford Motor Company in which Leffel hydraulic turbines are in operation, providing hydro-electric power. You can make sure of satisfaction with *your* hydraulic turbine installation by calling on Leffel for friendly, experienced, intelligent co-operation.

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THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 89 YEARS

FASTER, TRUER DRILLING . . .

Holes at all angles and in all positions. Operators fresh throughout the shift. The CLIMAX "Maxleg" achieves all these. The pneumatic feed can be instantly adjusted according to the type of rock and keeps the bit firmly up to the work. It takes all the weight and thrust off the operator. Please send for Publication No. 102.

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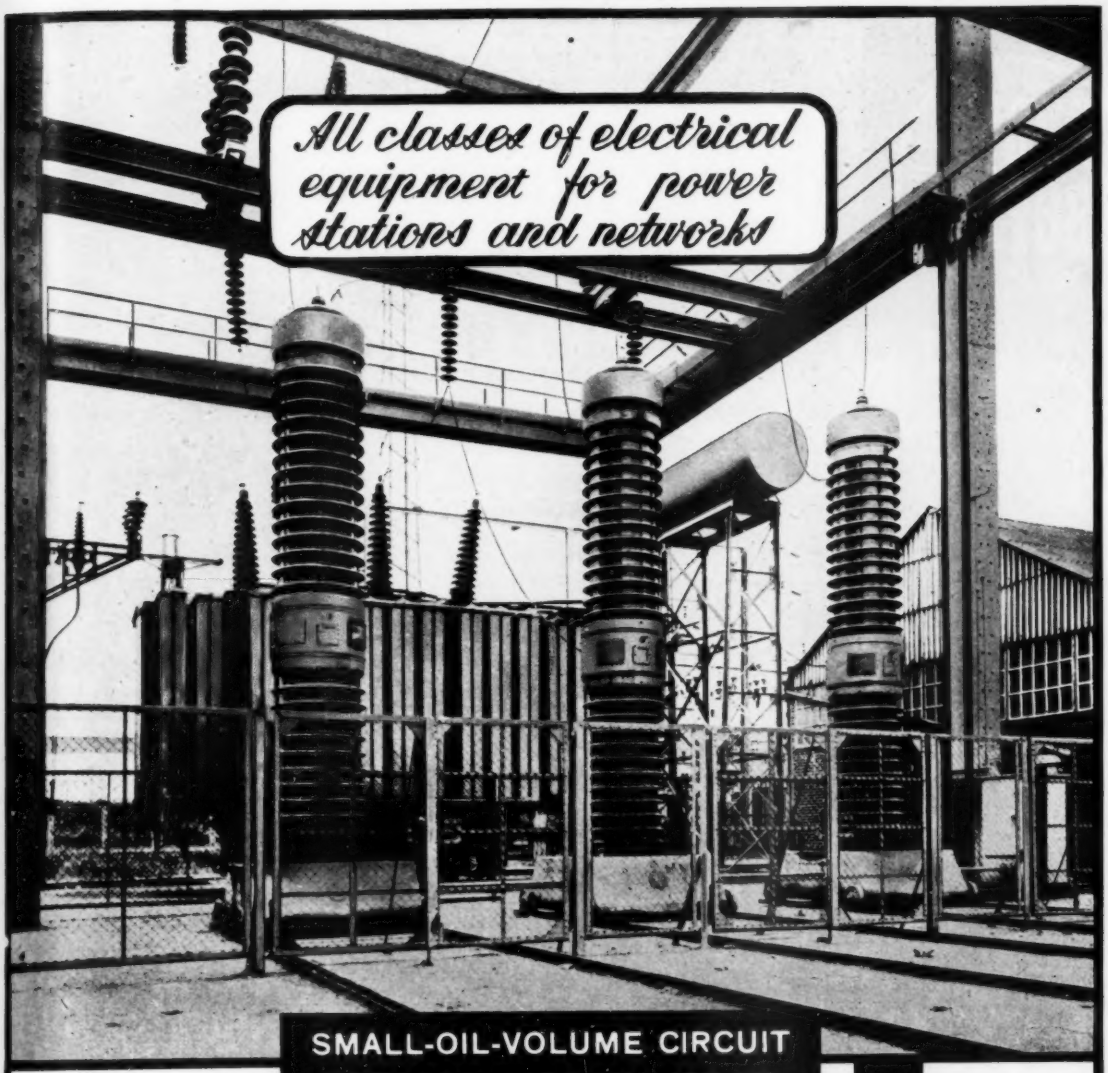

SMALL-OIL-VOLUME CIRCUIT BREAKER TYPE MH. 150 kV.
Installed at the Ville-sur-Haine power station of the Ste d'Electricité du Hainaut (Belgium)

ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHARLEROI

CHARLEROI (BELGIUM)

CHARLEROI CAEC

BROWN BOVERI

Air-Blast Circuit-Breakers

for Outdoor Erection and Voltages up to 380 kV

① High reliability
② Single- and three-phase high-speed reclosing
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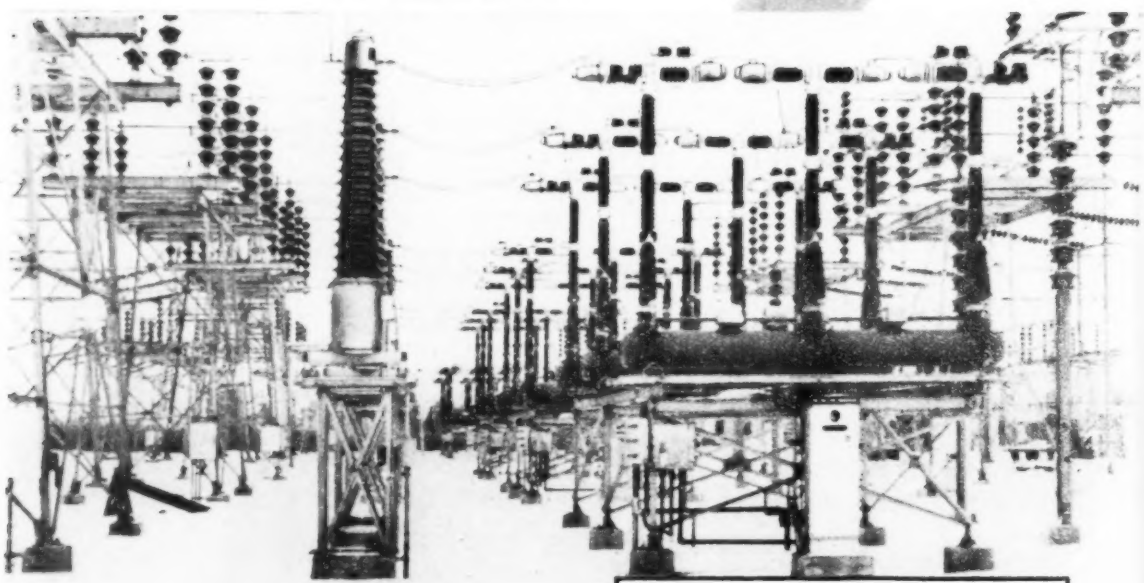
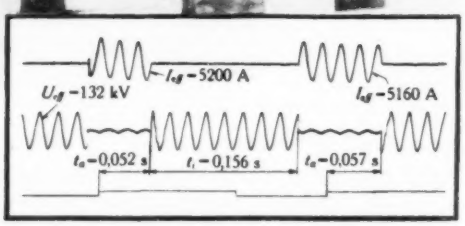


Brown Boveri 220-kV air-blast circuit-breakers n a Canadian outdoor station



t_s = Breaking times
t_t = Dead time

For reliable system operation install our air-blast high-speed circuit-breakers with automatic high-speed reclosing, in conjunction with our rapid and selective relays for electrical-system protection. Over 10 000 indoor and 1200 outdoor high-voltage air-blast circuit-breakers have already proved their worth in service over a period of many years.

BROWN, BOVERI & CO., LTD., BADEN SWITZERLAND

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HYDRAULIC TURBINES

Water power has been a dominant factor in Canada's tremendous modern advance—and over half the water power developed in Canada has been harnessed by Dominion Engineering Hydraulic Turbines.

In Canada and abroad, the Francis, Propeller and Impulse Type Turbines already installed or now under construction at Dominion Engineering represent a total installed capacity of over 6,000,000 H.P.

The facilities and experience indicated by such a record are at your service anywhere in the world.

Write for General Bulletin No. 201 on Dominion Hydraulic Turbines.

Dominion Engineering Works at Montreal, Canada

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COMPANY LIMITED

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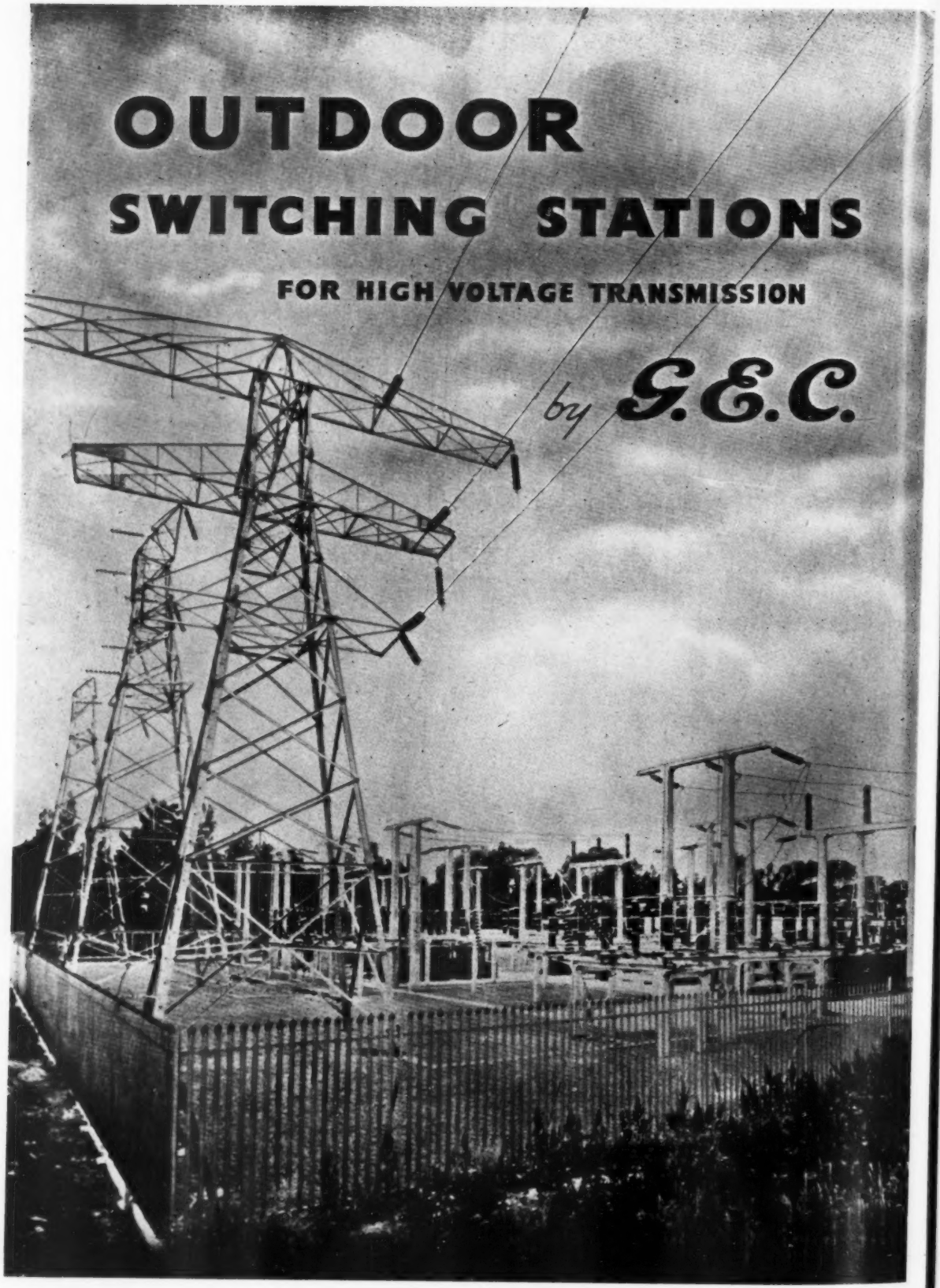

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

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Time is the most important thing in contracting. And putting every working hour to better use is the vital part played by CP equipment on contracting jobs of every description. Not only in Great Britain, but throughout the world, CP compressors, tools and accessories are specified because of their speedy operation and the high engineering standards to which they are made. Steady, dependable performance in compressors . . . reliability, ruggedness and handling comfort in pneumatic tools . . . readily available technical advice, service and sales are among the notable advantages to be had through standardisation of CP equipment. Demolition tools, pneumatic picks, sludge and sump pumps, pneumatic and electric vibrators, along with a full range of CP accessories, give contractors extra speed, extra efficiency and, above all, that extra reliability so vital to ensure consistent operation. Speed up contracting work by standardising on the equipment with a reputation for long-term dependability, so . . .

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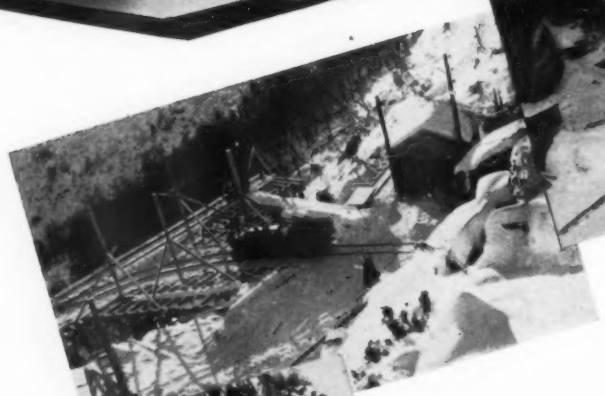

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NO FUEL PROBLEMS
LARGE OVERLOAD CAPACITY
ALL WORKING PARTS READILY ACCESSIBLE

EASY TO HANDLE
LOW MAINTENANCE COSTS
EASY START AND STOP

Trolley Locomotives in sizes from 5 to 15 tons, Gauge 19in. to 42in. with Trolley, Slipper or Pantagraph Collector.

Battery types in sizes from 2 to 12 tons. Gauge 18in. to 42in. Battery container easily removable.

The illustrations show combined Trolley Battery Locomotives supplied to the Vest Agder Hydro-Electric Scheme in Norway

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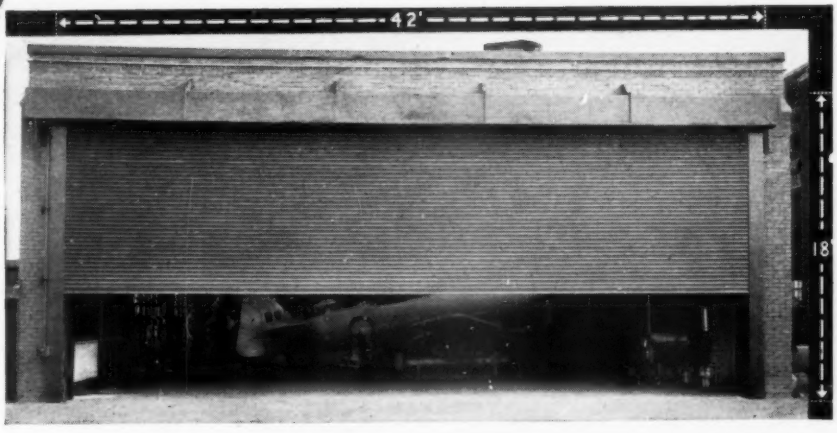
Like Britain

CANADA CHOOSES BRADY

Land of unusual attainments, Canada also has unusual requirements, but when the Canadian Car & Foundry Company of Montreal wanted a giant 'rolling door' far beyond the usual specification, it was not beyond Brady. Ordered on January 28th, 1949, it was despatched on July 12th, 1949, and in operation on August 5th, 1949; proof that the Brady organisation can tackle out-of-the-ordinary rolling shutter problems as efficiently as the standard installations which have won 'Brady Roller Shutters' an international grading.

This Brady project, 42' × 18' is an object of interest in Montreal, commercial capital of the Dominion, headquarters of the C.P.R., where it is one of the largest 'rolling doors' ever planned and created.



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Manufacturers of Brady Hand and Power Operated Lifts

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SHOP WINDOW FOR BRITISH ENGINEERING

Tummel-Garry Scheme, Pitlochry Dam

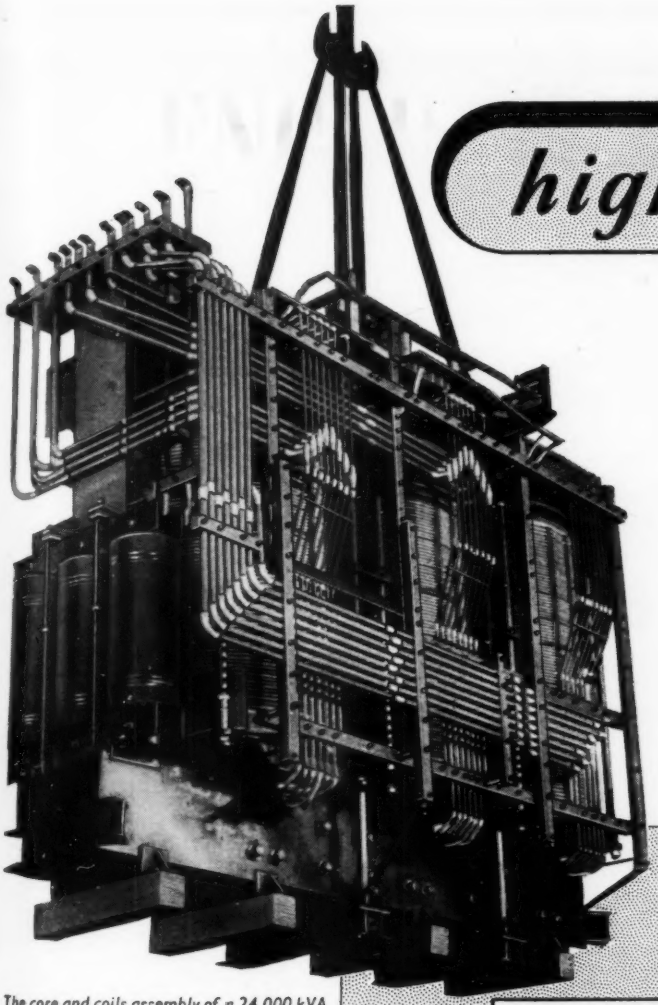
The North of Scotland Hydro-Electric Board are harnessing the water power resources of the Highlands of Scotland, which are estimated to have a potential annual output of 10,000,000,000 kilowatt hours, distributing electricity in an area of 21,750 square miles and also supplying power to Britain's National Grid.

More than one hundred hydro-electric schemes are visualised in this development.

Schemes with an estimated annual output of 3,300,000,000 kilowatt hours and a kilowatt capacity of 1,126,000 are in operation, under construction or in preparation.

On the doorstep of world-famous engineering firms the visitor will see a wide range of generating machinery and equipment operating under diverse conditions.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD



The core and coils assembly of a 24,000 kVA water-cooled Hackbridge Transformer for installation at a British Power Station.

high quality

outstanding feature of

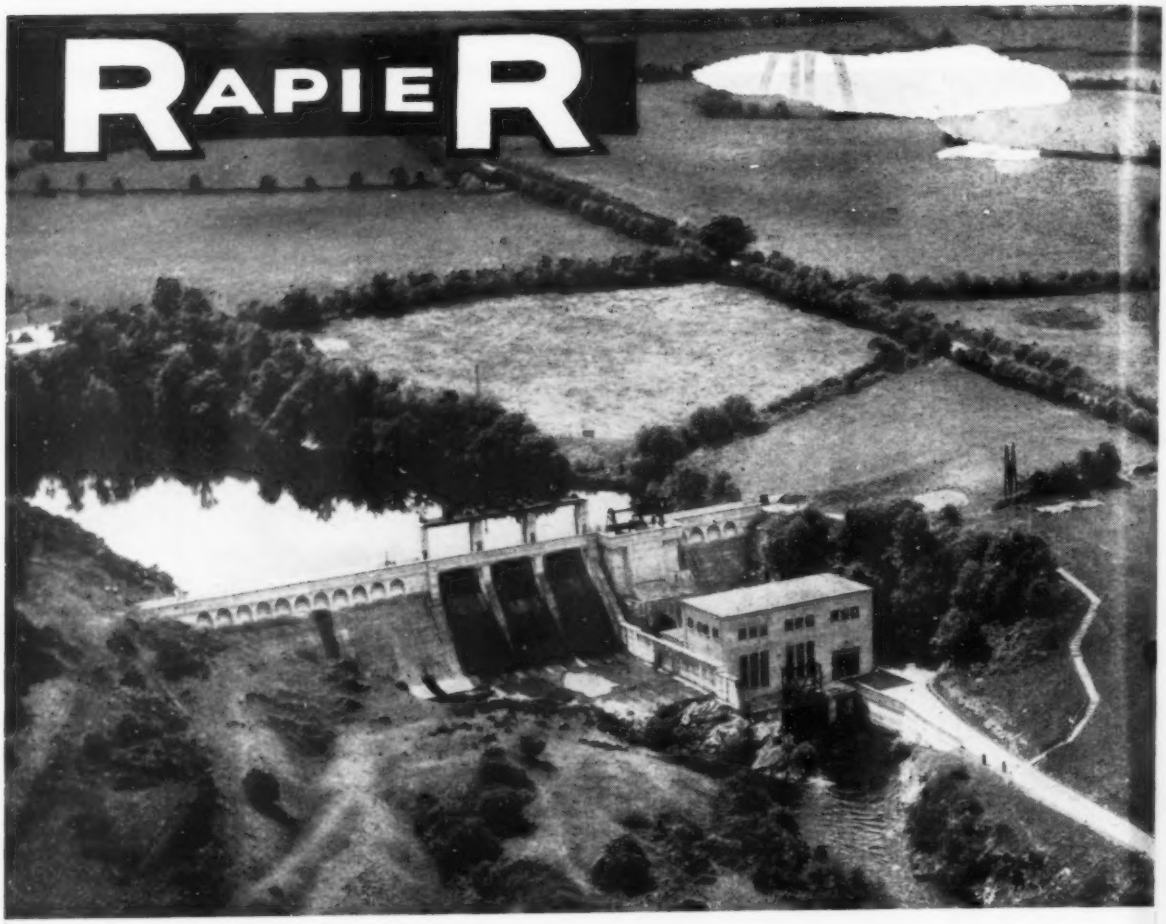
HACKBRIDGE TRANSFORMERS

TRANSMISSION and Distribution Engineers the world over have learnt from long experience to look up to the high quality of design and workmanship in HACKBRIDGE Transformers.

The Hackbridge and Hewittic Electric Co. Ltd. is very proud of this reputation, sustained for more than a quarter of a century, during which over **SEVENTEEN MILLION kVA** of Hackbridge transformers have been manufactured, many for Hydro-electric Stations—including a number of the world's largest units.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD., WALTON-ON-THAMES, SURREY

Telephone: Walton-on-Thames 760 (8 lines) Telegrams: "Electric," Walton-on-Thames



A typical installation of RapieR Gates for Spillway and Tailrace at the Golden Falls Hydro-Electric Generating Station on the River Liffey, Eire.

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for

Power Plants **Water Supply**

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ENGLAND

IPSWICH—Waterside Works

32 Victoria Street—**LONDON**

Photograph reproduced by kind permission of the Electricity Supply Board, Eire.

'ENGLISH ELECTRIC'
transformers

Scotland's latest and largest hydro-electric power source, the Loch Sloy scheme, has been equipped almost in its entirety by 'English Electric'. With an output of 130,000-kW from its four generators, the station depends on other 'English Electric' equipment for the control of output and distribution.

Power is generated at 11-kV and is stepped-up to 132-kV for delivery to the transmission lines via four 'English Electric' type OFW transformers each of 35,000-kVA rating. These transformers are typical of many similar 'English Electric' installations throughout the world.

The English Electric Company design and manufacture transformers of all types, up to the largest size and highest voltage.

The ENGLISH ELECTRIC Company Limited

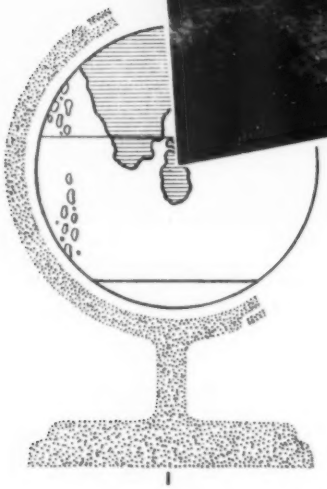
QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Transformer Department, Stafford.

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

TH.I.

CEYLON HYDRO-ELECTRIC SCHEME



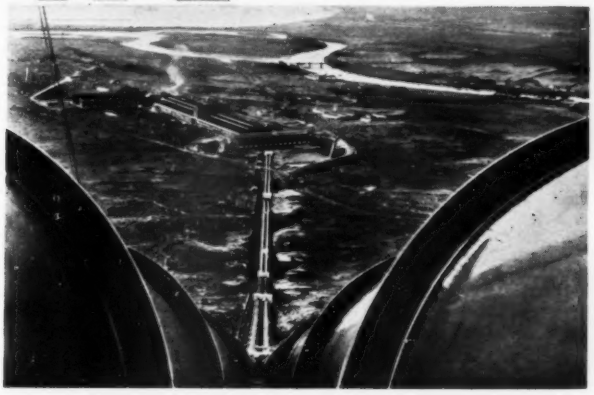
We have been privileged to co-operate in yet another important overseas hydro-electric contract—for the Norton Bridge Power Station at Hatton, Ceylon.

For this contract 2,000 tons of South Durham Steel Pipelines were manufactured, erected, and welded and tested in situ by South Durham engineers and skilled workmen. Our experience in this field and the assistance of our advisory staff are always at your service.

SOUTH DURHAM STEEL PIPES

South Durham Steel & Iron Co. Ltd., Pipe Dept: Stockton-on-Tees. Phone: Stockton-on-Tees 66117.

THE two illustrations show views of a section of the Lochaber Power Scheme, which involved the construction of three large Dams, about twenty miles of concrete lined Tunnels, five Pipelines each 3,200 feet long, a Power House, Factory foundations, Tail Race and ancillary works.

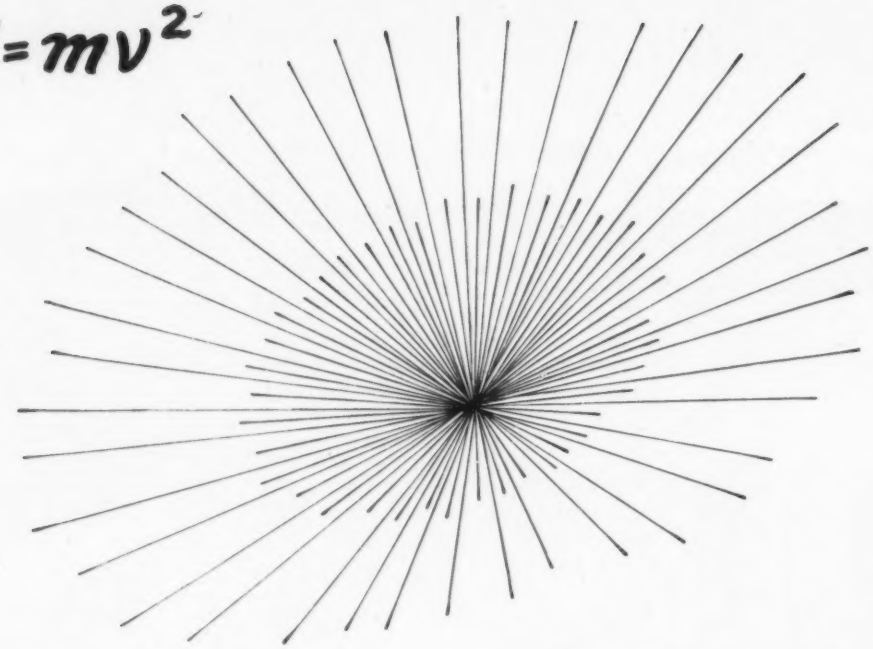


BALFOUR, BEATTY & Co. Limited

66 QUEEN STREET, LONDON, E.C.4. *Telephone : CITY 2046 (15 lines) Telegrams : RUOFLAB, CANNON, LONDON*

AND AT EDINBURGH BAGHDAD NAIROBI BUENOS AYRES

$E=mv^2$



... and the future

It is inevitable that nuclear energy will one day become a normal part of the routine of our lives, its use an every day occurrence, its control as consistently conformable to rule, and as much taken for granted, as electricity is today.

It is obvious that this control will require new forms of insulation, and undoubtedly somewhere in their construction porcelain will play a vital part . . . and it is equally obvious that only the finest porcelain will be good enough.

This being so it is certain that the stamp of Taylor Tunnicliff will be as much impressed on the future as it is upon the insulators of modern times.

TAYLOR, TUNNICLIFF PORCELAIN

TAYLOR, TUNNICLIFF & CO. LTD. *Head Office*: EASTWOOD · HANLEY · STAFFS · *Stoke-on-Trent 52724*
London: 125 HIGH HOLBORN, W.C.1. *Holborn 1951.* *Factories at*: *Hanley, Stone and Longton, Staffs.*

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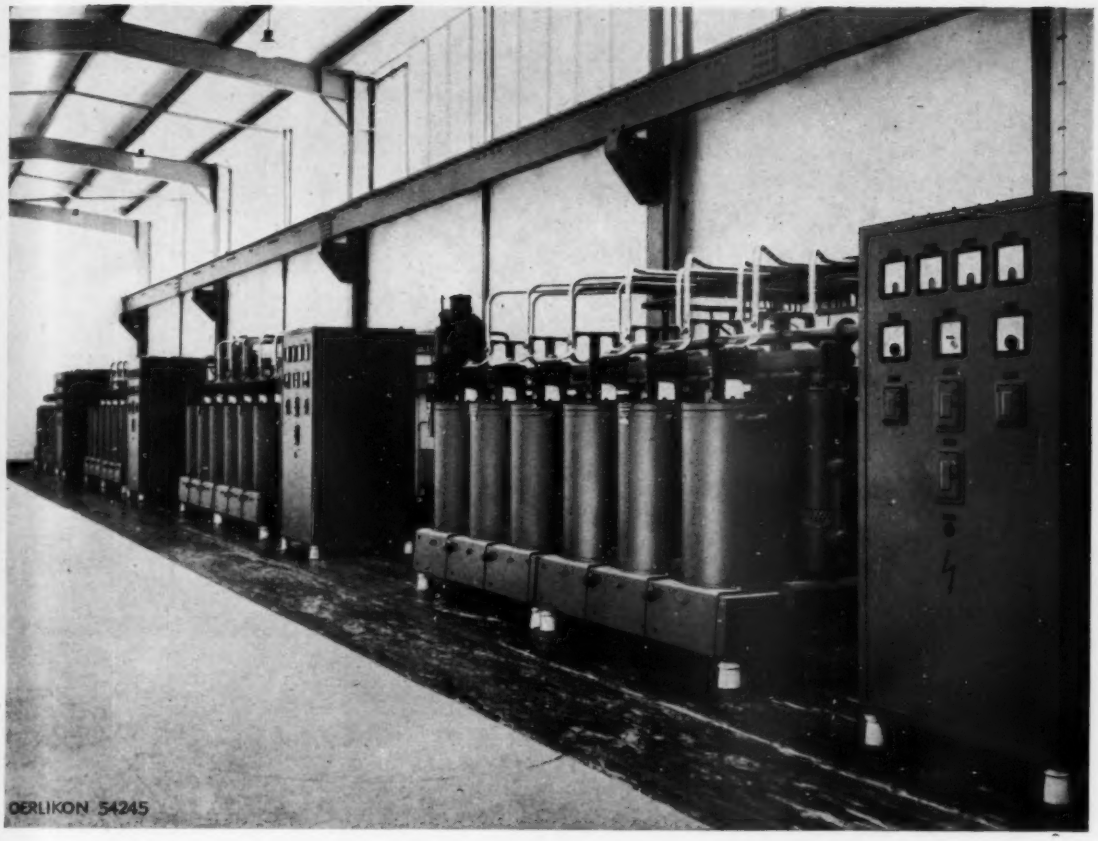
Electrical machinery and apparatus

known throughout the World for more than 75 years!



Four Oerlikon single anode rectifier units each for 4500 kW, 6000 A, 750 V, in an electrochemical plant.

OERLIKON PRODUCTS:

Complete electrical equipments for hydro-electric and steam power stations, sub-stations and distribution installations.

Generators, Motors, Transformers, Mercury Rectifiers, Induction Regulators ; Motor Generator Sets. **Electrical Apparatus** for High and Low Voltage (Oil Circuit-Breakers, Minimum Oil Circuit-Breakers, Air-Blast Circuit-Breakers, Isolating Switches, Step-Switches, Protective Switch-boxes, etc.) Voltage Regulators ; Relays, Lightning Arresters. Switch and Distribution Stations. Arc Welding Plants.—**Electrolysers** for the production of Hydrogen and Oxygen.

Steam and Gas Turbines. Turbo-Alternators.

Electrical Equipments for Locomotives, Motor Coaches, High-Speed Railcars, Diesel Electric Vehicles, etc. (for Standard and Narrow Gauge Railways, for Mountain and Rack Railways, etc.), Tramways, Trolleybuses, Ropeways, Cable Railways, Snow ploughs. — Vehicles with electrogyro drive. — Compressors and Vacuum Pumps for Vehicles. — Rectifier Plants.

OERLIKON ENGINEERING COMPANY, ZURICH 50 (SWITZERLAND)

TUNNEL DRIVING AT BOWLAND FOR MANCHESTER CORPORATION WATERWORKS
Engineer and Manager—Alan Atkinson, Esq., M.Eng., M.I.C.E., M.Inst.W.E.

The CEMENTATION COMPANY LIMITED

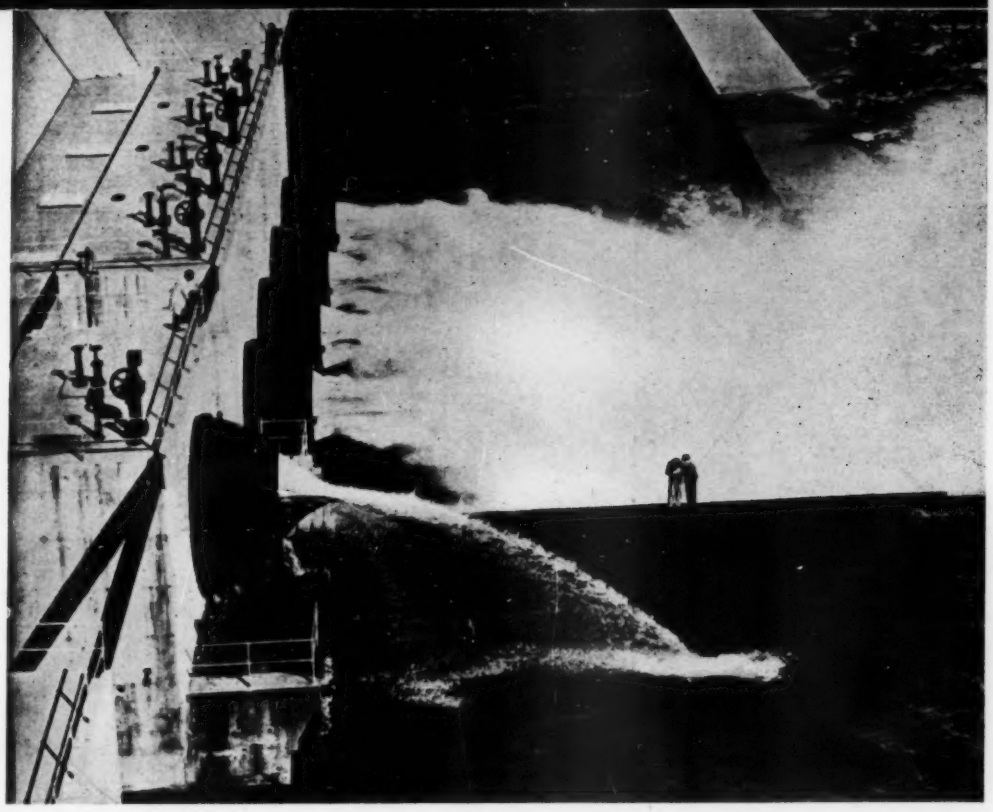
This tunnel, ten miles long, forms the middle section of the aqueduct which when completed will bring water from Haweswater in the Lake District to Manchester. The conditions for tunnelling under the Bowland Hills are difficult, varying from soft mudstones to sandstones containing water at high pressure, such as in the heading shown above from which over two million gallons of water are being pumped each day. Despite these varying and difficult conditions, a progress of 236 feet has been obtained in one week in ground requiring continuous steel arch support right up to the face.

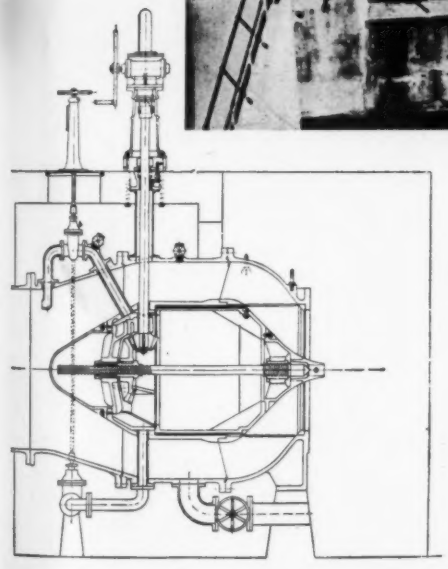
BENTLEY WORKS — DONCASTER

TELEPHONE: DONCASTER 54177-8-9

LONDON OFFICE 39 VICTORIA STREET, S.W.1 - - TELEPHONE ABBEY 5726-7-8

DISCHARGE REGULATORS FOR DAM OUTLETS





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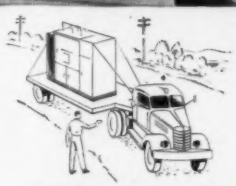

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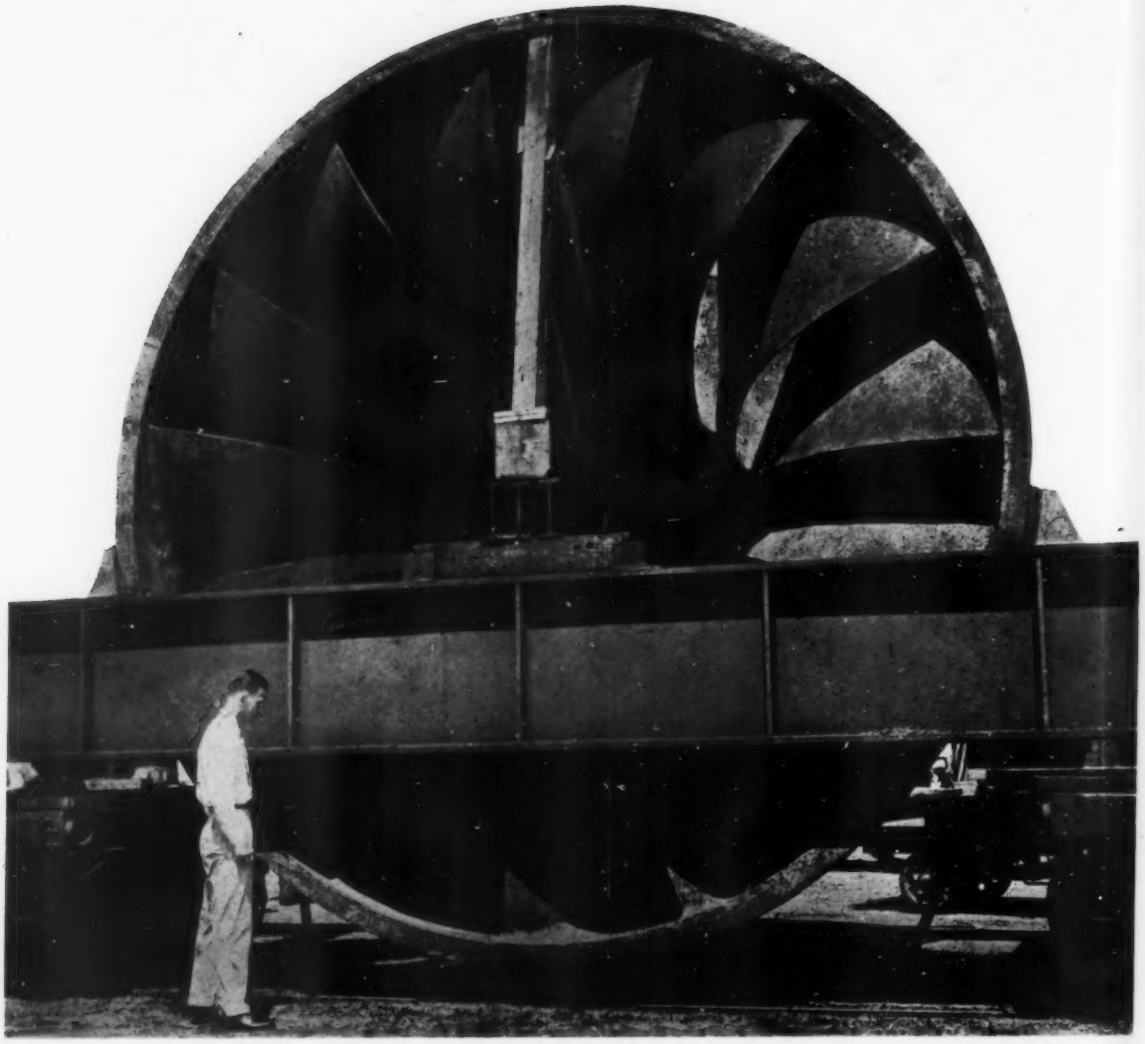

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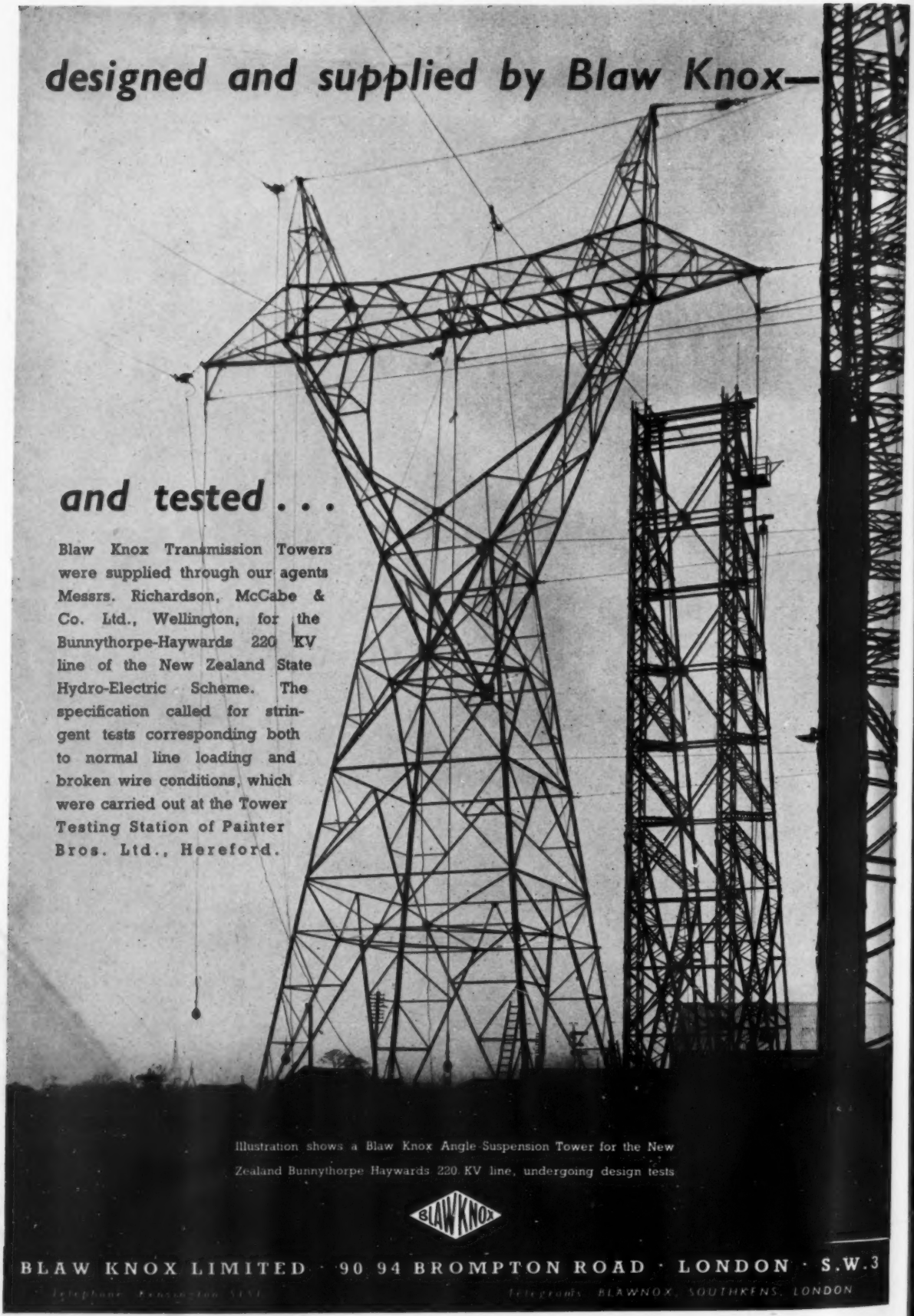

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Illustration shows a Blaw Knox Angle Suspension Tower for the New Zealand Bunnythorpe Haywards 220 KV line, undergoing design tests

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Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466.
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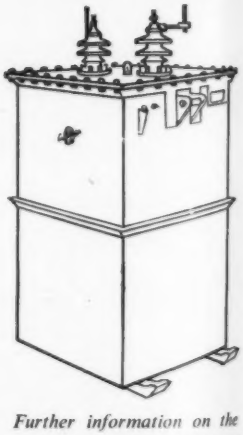

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The Human Element

WE have published from time to time articles and notes which indicate the increasingly extensive schemes which have been instituted for training hydro-electric engineers, particularly in those countries with large resources of water power. In due course, the engineers who issue from institutions having such schemes of training will be equipped with a far wider and better balanced range of theoretical tools than has been the case in the past.

There is, however, one aspect of hydro-electric engineering which cannot be taught in any training college however assiduously its teachers and students work. The very nature of the harnessing of water means that there are probably more imponderables and empirically-determined factors than in any other field of power generation. For instance, the estimation of statistics of rainfall over a lengthy period is not an exact science, as was shown by the many papers devoted to this subject at the New Delhi World Power Conference this year, and by the diversity of the views expressed by the leading authorities. A combination of judgement, experience, and luck is needed before a decision can be made.

The moods of the river during the construction period offer another aspect of the work where the unpredictable nature of the water's turbulence and ebb and flow with the seasonal variation can exercise a profound effect on the cost of the diversion works, and on the safety of the construction work as it proceeds. The death of 19 workers, caused by a 150,000-ton avalanche of ice and snow being precipitated into a lake, thus causing a flash flood, was recorded in a recent issue.

The most perfect plan may fail, economically, through a wrong estimation of the capacity of local labour to carry out the work in the due time and under the site conditions available. The necessity for both the engineers and the local labouring forces to live on an isolated site, which for days and weeks at a time may be snowbound or cut off from all civilised amenities, offers innumerable possibilities of labour unrest; or on the other hand, of the creation of a fine team which will pull together all the better for having to live, sleep and have their whole being on the job. The "sensing" of the atmosphere in regard to labour troubles, and the detection of agitation leading to stoppages for reasons other than just and equitable causes, is something which calls for a high degree of experience in the handling of men, and anyone without such experience may well cost his employers a vast sum of money which will in the end turn their profit into a considerable loss.

How is a man, after his theoretical training, to gain experience of this type? It is obvious that he must work on many projects before he is equipped to take charge of any operation, however small. He must have travelled as widely as possible, and during his travels he must have used every conceivable opportunity to gain experience. It is not sufficient for him to have concentrated on the job immediately in hand; he must learn something of the work of the other men, both those employed on simple manual tasks and those engaged in the design, production planning, transport, management, civil, hydraulic, and electrical engineering aspects of the scheme. He must have learned something of labour conditions in countries with widely diverse industrial backgrounds. He must have gathered a good deal about the framework of trade-union structure and its negotiating machinery.

It may be that in addition to years spent in a sound theoretical training (and yet no more years are necessary than those needed to become a doctor or an architect), it would be too much to demand of a man that he shall gain this extra experience in fields other than those directly concerned with engineering matters. Nevertheless, in these days of intense specialisation there is always the danger of complete lack of all-round engineers in a generation's time. Unless employers' organisations or State Power Boards, or perhaps Governmental and extra-Governmental agencies, such as Unesco, are willing

to subsidise, by means of travelling fellowships and the like, the further training of young engineers destined to construct and operate the world's hydro-electric systems in the years to come, it is possible that there may be a regrettable shortage in the supply of the right type of engineer.

Loan to India

THE third International Bank loan to India—18·5 million dollars, has been made by the International Bank of Reconstruction and Development for the expansion of the Damodar Valley multi-purpose scheme, which includes flood control and electric power generation and transmission as well as extensive irrigation. The loan agreement was signed in Washington by the Indian Ambassador, Mrs. Vijaya Lakshmi Pandit and the Vice-President of the bank, Mr. Robert Garner. It will finance part of India's dollar payments in the United States and Canada for power house equipment for the Bokaro thermal plant, construction equipment for the Konar Dam, and other machinery required for the Damodar Valley project. The balance will be found from India's own resources.

Vital Aid to Industry

IN a statement dealing with the purposes of the loan the Bank points out that the substantial increase in availability of electrical energy in the Damodar Valley region would be a key factor in raising India's coal output and in lowering the cost of coal production. "Completion of the Bokaro Konar project," it adds, "will provide at reasonable rates the urgently needed electrical energy for the expansion of coal production and the further electrification of the coal mines. The Damodar Valley, with its rich mineral deposits, is a favourable site for a number of heavy industries using iron, steel and other basic raw materials."

Hirakud Dam Progress

THE Hirakud Dam project, Orissa, India, which will be completed in about two years, will help to bring under irrigation about 1,500 square miles within that state, the Minister of Natural Resources and Scientific Research announces. It is the biggest of the three irrigation schemes of Orissa State, and includes the construction of a great dam across the River Mahanadi, where two hydro-electric plants will be erected. The project, estimated to cost Rs.480 million, is scheduled to be completed as part of the seven year plan of the Government before 1955.

Comparison with Dnieper

RISING 150 feet from the river bed the Hirakud Dam will be comparable in size and importance to the Dnieper Dam in Russia's Ukraine. The span across the main channel will be nearly three miles, with a 17 mile stretch of low dykes on both sides. The reservoir formed by the dam will rise to 625 feet above sea level, and will have a storage capacity of 5·3 million acre feet of water, of which 1·2 million acre feet will be for dead storage. The remaining 4·1 million acre feet will be for irrigation, flood control, hydro-electric power generation and improving inland navigation. This new and extensive cheap power supply will greatly benefit the mining areas of Orissa, which are rich in coal, iron, bauxite and other important raw materials.

Experts for Pakistan

UNDER the technical assistance programme of Unesco (United Nations Educational, Social and Cultural Organisation) for the planning and development of geophysical work in Pakistan the first technical expert, Dr. G. Norgaard, of Denmark, is now at work in the country. Three other experts—on terrestrial magnetism and electricity, seismology and atmospheric physics—are also to carry out investigations.

New Plant for Quebec

DETAILS of plans for the construction of another hydro-electric power plant in the province of Quebec have been given by Mr. Nathaniel Davis, of Aluminium Limited, at a shareholders' meeting in Montreal, at which he also spoke of the prospects for the expansion of aluminium production in British Columbia. They are a part of big developments to be undertaken by the Aluminium Company of Canada, a subsidiary, at a cost of well over 200 million dollars, towards which a 40 million dollar loan is being negotiated with Great Britain. The projected 200,000 h.p. hydro-electric plant at Chute Savanne, on the Peribonka River in north-eastern Quebec, is estimated to cost about 60 million dollars. Another big power scheme is planned for a vast undeveloped area some 400 miles north-east of Vancouver, in which water from several lakes will be tunnelled ten miles beneath mountains to a power house some thousands of feet below.

Underground Hydro-electric Plants

A REVIEW of 60 underground hydro-electric plants in various parts of the world, having a total capacity of over seven million kW, was recently given before the American Society of Civil Engineering by Joseph D. Lewin, New York engineer. There has been rapid development of underground power plants all over the world since the first one was placed in operation at Buchbergmuehle in Germany in 1907.

Neither geographic, climatic nor topographic factors seem to limit the use of underground hydro-electric plant, according to Mr. Lewin. From north of the Arctic Circle, where the Swedish Porjus and Harspranget plants and the Russian Niva plant have been built, to southern Italy, where the Flumendosa plant is situated, from the Sulak in the eastern Caucasus to the Bromat and Baton plants in France, underground plants are to be found. Even south of the Equator, in Peru and Australia, there are such developments. Underground power plants have been built at all elevations and the units range from a 31 h.p. plant in Friedigen, Germany, to a 2,800,000 kW development on the Snowy River in Australia.

These plants are constructed in all types of rock, igneous, sedimentary and metamorphic; some are built in hard, sound rocks like the granites of Sweden, requiring practically no supports, while a few have

been built in badly fissured, even disintegrated rocks requiring substantial and nearly continuous roof supports.

Analysis shows that costs, Mr. Lewin points out, are as much as 40 per cent. less than conventional surface developments, most of the savings being due to shorter developments, elimination of penstocks and valves, and savings in tunnel linings. Rock is utilised as a structural material and made to carry loads. Underground developments require less operating expense. The cost of excavation is 90 per cent. of the investment. Based on prevailing American labour costs, it appears that European tunelling methods may reduce the cost of rock excavation by as much as 60 per cent. A new development in lining circular pressure tunnels is the use of prestressed concrete. The blocks may also be treated with asphalt to improve their watertightness and to reduce friction losses.

Volta River Project

IN the House of Commons on May 9th, Mr. John Grimston asked the Secretary of State for the Colonies if he could yet make a statement on the proposal to establish a hydro-electric plant and an aluminium reduction works on the Volta river in the Gold Coast.

Mr. Dugdale said Aluminium Limited of Montreal and the British Aluminium Company had made a joint examination of alternative projects for establishing aluminium smelters in North Borneo or the Gold Coast. The results of this examination were under consideration and further discussions with the companies and considerable further technical investigation in the Gold Coast would be necessary before a decision could be taken to proceed with either scheme.

U.S. and "Snowy" Plans

THE keen interest of United States engineers in Australia's gigantic Snowy River hydro-electric project is shown in the visits paid to the country by various experts. Two of them, Mr. Holt and Mr. Wellman, of the San Francisco firm of Guy F. Atkinson and Company, recently spent some time in New South Wales and Victoria and have now returned to their own country by air. Both expressed the view that the scheme should have been started ten years ago, but now that a beginning had been made it was of first importance that the work should be expedited in every possible way because of Australia's constantly rising demand for power for industry and domestic consumption. The firm, it is understood, has tendered for part of the project which the engineers liken in some respects to the Tennessee Valley Authority's great undertaking.

Switzerland's Economy

FIVE main factors are calculated to have the greatest influence on the future economy of Switzerland, according to the bulletin of the Swiss Bank Corporation. Principal among these are increased activity in building due to national defence requirements, hydro-electric schemes and other building programmes. In a note on Swiss corporations in 1950 it is shown that there were 20,326 corporations with a share capital of 8,576 million francs. Capital increases during the year totalled 322 million francs, all sectors except that of the hotel industry showing advances. The biggest individual increase was in the electricity, gas and water sector, with a rise of 163 million francs. Total concentration of capital in the electricity, gas and water companies is 820 million francs.

Faroe Islands New Project

A DELEGATION from the Faroe Islands has arrived in Denmark in order to close contracts with several firms, including Hojgaard and Schultz regarding the building of hydro-electric plant in the Faroe Islands. It is the intention to use water power from the waterfall at Vestmanhavn for the production of electricity to supply the Islands of Strømo, Østerø and Vaagø.

According to estimates from the engineering firm of P. A. Pederson, at the end of 1948, the total cost of the scheme would be 14 million kroner; but owing to the increase in prices since that date, the firm estimates the present building price to be 16.7 mill. kr.

After negotiations the following finance plan was agreed to on the basis of the project costing 14 million kroner.

Capital put up by SEV	1·0	mill. kr.
Loan of 2 mill. kr. from the Faroe Savings Bank @ 5 per cent. for 30 years, to be paid yearly at the rate of 6·51 per cent.	2·0	„ „
Obligations loan from the Faroese Banks Banks @ 5 per cent. to be repaid over a period of 30 years	1·0	„ „
Marshall Loan	3·0	„ „
Danish States Loan of half the cost of the project, but highest 7 mill. kr. ...	7·0	„ „
	14·0	„ „

The Danish States Loan will be free from payment of instalments and interest until the project is ready for use. Thereafter 4·2 mill. kroner shall be repaid over a period of 40 years, by payment of 105,000 kr. yearly. The first 10 years after the project is finished, the interest shall be raised, but afterwards will be reduced to 3 per cent. The conditions for the Danish States Loan are that the Faroese Government shall subsidise the interest for those loans which have been taken up in the Faroes in such a manner that the Lagting (Faroese Parliament) for the above mentioned Savings Bank Loan of two mill. kr. and the Obligations Loan of one mill. kroner gives a full interest subsidy during the period of building and in the following 10 years.

According to temporary estimates the building will proceed in such a manner that the money shall be used according to the following time schedule:

1951—1952	SEV's Capital ...	0·8	mill. kr.		
	Marshall Help ...	3·0	„ „	3·8	mill. kr.
1952—1953	SEV's Capital ...	0·1	„ „		
	Danish States Loan	4·0	„ „		
	Faroe Savings Bank Loan ...	2·0	„ „	6·1	„ „
1953—1954	SEV's Capital ...	0·1	„ „		
	Danish States Loan	3·0	„ „		
	Faroe Obligation Loan ...	1·0	„ „	4·1	„ „
				14·0	„ „

Volta River Project

THE London firm of consulting engineers, Sir William Halcrow and Partners, who are the Consultants to the Gold Coast Government for the Development of the Volta basin, have now been at work in the Gold Coast for over a year, and they have issued a preliminary report. Their terms of reference call for a report on the Volta basin from the aspects of (1) development of hydro-electric power at Ajena on the lower Volta, and / or at Bui on the Black Volta; (2) irrigation and drainage; (3) river navigation and (4) transport. They are working in conjunction with Government geologists, soil scientists, medical specialists and topographical surveyors; and are carrying out their investigations, in part, through several well-known specialist firms.

The consultants consider that the very comprehensive plans for the development of the Volta river can be undertaken only if the main project — the production of hydro-electric power at Ajena — is found both practicable and economic. Neither the present nor the future demand for electricity for domestic and industrial consumption is sufficient in itself to justify a large hydro-electric project, but if the project for the manufacture of aluminium is proceeded with and becomes the main outlet for the electric power produced, then the scheme may well be economically justified.

As regards dam sites the site at Ajena chosen by West African Aluminium Ltd. appears to be the best topographically, and deep drilling operations here are being conducted by Aluminium Ltd., of Canada. At a second possible dam site near Misikrom, above Ajena, drilling work is being carried out by a British firm, the Cementation Co. Ltd. As a preliminary to this work the consultants arranged for a London firm, Geophysical Services Ltd., to undertake highly specialised investigations in the locality of Misikrom, and for Prof. J. D. C. Anderson, of Cardiff University, to report on a certain special aspect of the geological structure.

The main object of the Volta scheme would be to produce aluminium, and the consultants estimate that the Volta river could be harnessed to produce 545,000 kW of hydro-electric power for this purpose. A grid system would take surplus power to Accra, Sekondi-Takoradi, the mining areas and Kumasi. Other proposals include railway lines to bring bauxite from Yenahin to the aluminium factory, and to carry the finished aluminium to a proposed new seaport east of Accra for export.

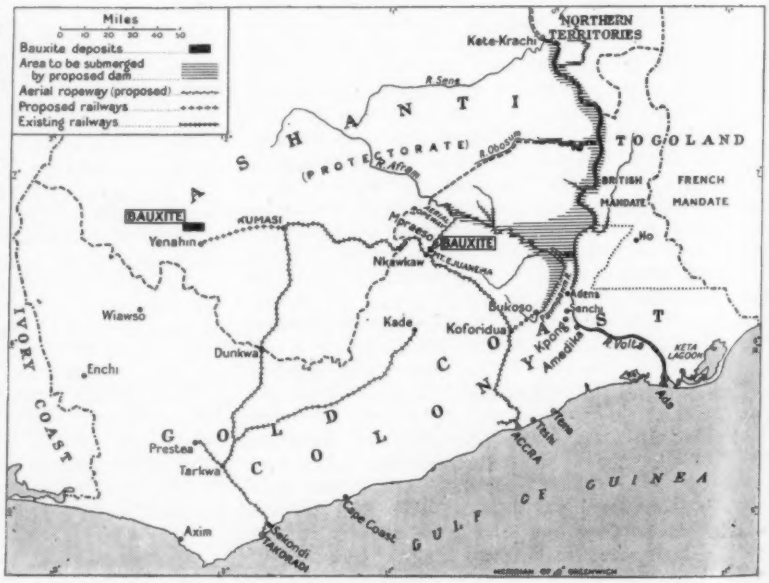
The localities of Ada, Teshie and Tema have been under consideration as possible sites for the new harbour, and the preliminary survey has suggested that the Tema area might provide a suitable site. The firm of Kelvin and Hughes (Marine) Ltd. is now busy carrying out a survey of the coast and of the sea-bed at Teshie and Tema.

Irrigation possibilities have also been studied, and the consultants consider that an area of 500,000 acres in the Accra Plains could be irrigated by water brought in a canal from the proposed reservoir. Soil surveys to determine the suitability of the soils for irrigation are being carried out by parties provided by the Soil Survey division of the Department of Agriculture. As irrigation farming is new to the Gold Coast, arrangements are in hand for a small trial irrigation scheme near Kpong.

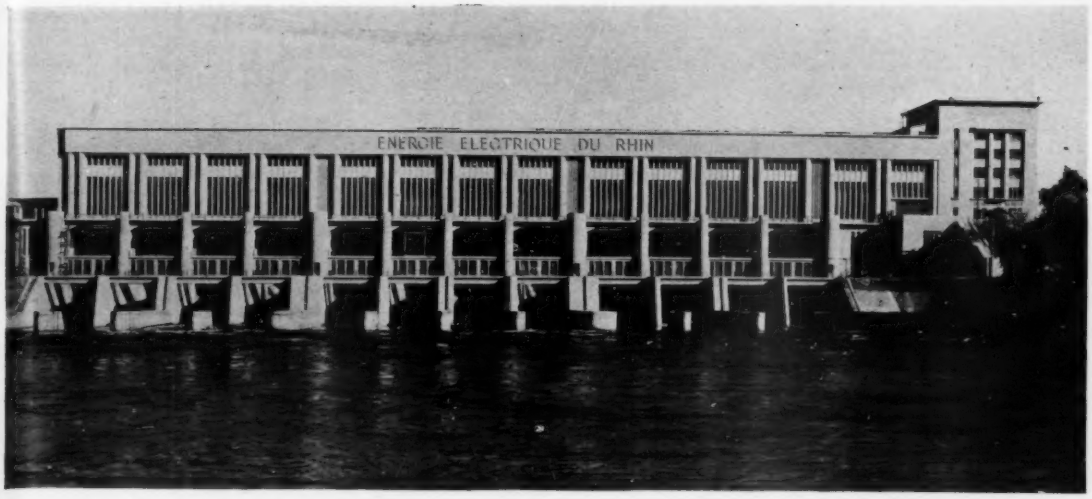
An aerial survey of the proposed reservoir area is being undertaken by the Directorate of Colonial Surveys, and the aerial photography is being done by the Royal Air Force, based on Takoradi. Certain river gauge readings and other similar work are also being undertaken.

An extensive survey of the medical entomology of the whole area was carried out in 1950 by Dr. Lewin Berner, of the University of Florida. Another American expert, Dr. Elmer G. Berry, is investigating bilharzia in the Volta valley.

The scheme is expected to cost at least £100 million, and the problem of financing it is being very thoroughly considered both in the Gold Coast and in London, where proposals are being worked out in consultation with H.M. Government. At the same time the aluminium companies are considering whether they will invest in the mining of bauxite and in an aluminium factory.



Map of the Volta river district



Kembs power station on the Rhine (1932) containing six 25,000 kW sets operating at a head of 16·7 m.

The French Hydro-Electrical Industry

Part One: A comprehensive account of the evolution and development of the French hydro-electric industry and a forecast of its probable expansion, by PIERRE CHEVRIER and STÉPHANE FERRY, respectively Directeur-Adjoint and Ingénieur en Chef, Service de la Production Hydraulique, Electricité de France.

ABOUT 1890, the hydraulic production of mechanical energy through relatively high-power turbines, the conversion of that energy into electric power and the development of energy transmission systems, entered an era of important industrial application. The conjunction of these techniques led very quickly to the creation in the French Alps of a vigorous hydro-electric industry — *i.e.* producing electrical energy by means of hydraulic power.

We propose to summarise here the evolution and development of this industry in France from the beginning of the twentieth century and to sketch its prospects.

Period 1900-1918

In 1900 about 90 per cent. of the French hydro-electric production was concentrated in the Alps of Savoie and Dauphiné. The average yearly capacity in that region was estimated at some 800 million kWh; the actual production, however, fell notably below that figure since, through lack of means to adapt production to consumption, large volumes of available water were discharged.

Roughly 80 per cent. of the output was absorbed on the spot by industries installed near the power stations; electro-chemistry and electro-metallurgy (aluminium, calcium-carbide, ferro-alloys, etc.) were the most important. The remaining 20 per cent. was distributed as light and power over limited local networks. More than half the power distributed in 1900 was produced by the first important low-head power station at Cusset (head 8 to 12 metres, 12,000 kW), on a canal parallel with the Rhône; it supplied electricity to Lyons. High falls were already being used, notably the Calypso plant (600 metres, 10,000 kW); but no dams existed for the storage of important reserves of water for hydro-electrical purposes. Plants were downstream and the harnessed volume was far below the mean flow of the stream; thus feeding was hardly possible and seasonal regularization did not exist. Consumption, as far as possible, followed the pace of hydraulic availability. Electro-chemistry did its best according to the seasonal fluctuation of output, working 24 hours non-stop in the spring and summer and slowing-down in the winter.

Much water, however, was lost. The proportion of waste was inevitably considerable in the new networks exclusively supplied by hydraulic production. The need soon appeared for liaison and inter-connection between self-supplying electro-chemistry plants and distributing power stations. Moreover, a thermal contribution was necessary in important networks such as that of Lyons.

From 1900 to 1914, the new industry expanded

Volta River Project

THE London firm of consulting engineers, Sir William Halcrow and Partners, who are the Consultants to the Gold Coast Government for the Development of the Volta basin, have now been at work in the Gold Coast for over a year, and they have issued a preliminary report. Their terms of reference call for a report on the Volta basin from the aspects of (1) development of hydro-electric power at Ajena on the lower Volta, and / or at Bui on the Black Volta; (2) irrigation and drainage; (3) river navigation and (4) transport. They are working in conjunction with Government geologists, soil scientists, medical specialists and topographical surveyors; and are carrying out their investigations, in part, through several well-known specialist firms.

The consultants consider that the very comprehensive plans for the development of the Volta river can be undertaken only if the main project — the production of hydro-electric power at Ajena — is found both practicable and economic. Neither the present nor the future demand for electricity for domestic and industrial consumption is sufficient in itself to justify a large hydro-electric project, but if the project for the manufacture of aluminium is proceeded with and becomes the main outlet for the electric power produced, then the scheme may well be economically justified.

As regards dam sites the site at Ajena chosen by West African Aluminium Ltd. appears to be the best topographically, and deep drilling operations here are being conducted by Aluminium Ltd., of Canada. At a second possible dam site near Misikrom, above Ajena, drilling work is being carried out by a British firm, the Cementation Co. Ltd. As a preliminary to this work the consultants arranged for a London firm, Geophysical Services Ltd., to undertake highly specialised investigations in the locality of Misikrom, and for Prof. J. D. C. Anderson, of Cardiff University, to report on a certain special aspect of the geological structure.

The main object of the Volta scheme would be to produce aluminium, and the consultants estimate that the Volta river could be harnessed to produce 545,000 kW of hydro-electric power for this purpose. A grid system would take surplus power to Accra, Sekondi-Takoradi, the mining areas and Kumasi. Other proposals include railway lines to bring bauxite from Yenahin to the aluminium factory, and to carry the finished aluminium to a proposed new seaport east of Accra for export.

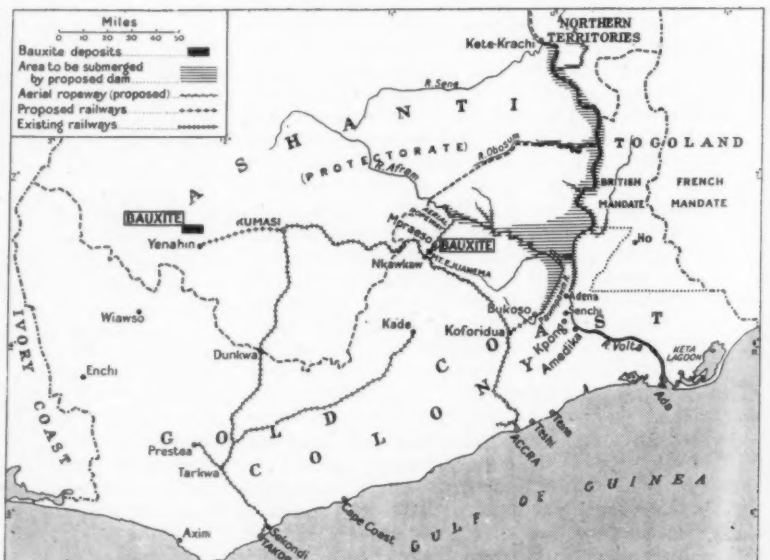
The localities of Ada, Teshie and Tema have been under consideration as possible sites for the new harbour, and the preliminary survey has suggested that the Tema area might provide a suitable site. The firm of Kelvin and Hughes (Marine) Ltd. is now busy carrying out a survey of the coast and of the sea-bed at Teshie and Tema.

Irrigation possibilities have also been studied, and the consultants consider that an area of 500,000 acres in the Accra Plains could be irrigated by water brought in a canal from the proposed reservoir. Soil surveys to determine the suitability of the soils for irrigation are being carried out by parties provided by the Soil Survey division of the Department of Agriculture. As irrigation farming is new to the Gold Coast, arrangements are in hand for a small trial irrigation scheme near Kpong.

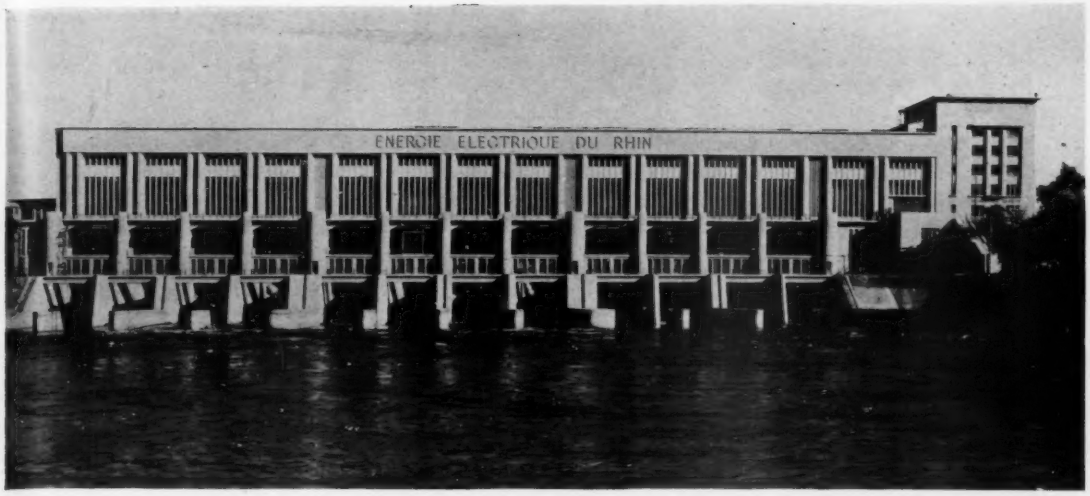
An aerial survey of the proposed reservoir area is being undertaken by the Directorate of Colonial Surveys, and the aerial photography is being done by the Royal Air Force, based on Takoradi. Certain river gauge readings and other similar work are also being undertaken.

An extensive survey of the medical entomology of the whole area was carried out in 1950 by Dr. Lewin Berner, of the University of Florida. Another American expert, Dr. Elmer G. Berry, is investigating bilharzia in the Volta valley.

The scheme is expected to cost at least £100 million, and the problem of financing it is being very thoroughly considered both in the Gold Coast and in London, where proposals are being worked out in consultation with H.M. Government. At the same time the aluminium companies are considering whether they will invest in the mining of bauxite and in an aluminium factory.



Map of the Volta river district



Kembs power station on the Rhine (1932) containing six 25,000 kW sets operating at a head of 16·7 m.

The French Hydro-Electrical Industry

Part One: A comprehensive account of the evolution and development of the French hydro-electric industry and a forecast of its probable expansion, by PIERRE CHEVRIER and STÉPHANE FERRY, respectively Directeur-Adjoint and Ingénieur en Chef, Service de la Production Hydraulique, Electricité de France.

ABOUT 1890, the hydraulic production of mechanical energy through relatively high-power turbines, the conversion of that energy into electric power and the development of energy transmission systems, entered an era of important industrial application. The conjunction of these techniques led very quickly to the creation in the French Alps of a vigorous hydro-electric industry — *i.e.* producing electrical energy by means of hydraulic power.

We propose to summarise here the evolution and development of this industry in France from the beginning of the twentieth century and to sketch its prospects.

Period 1900-1918

In 1900 about 90 per cent. of the French hydro-electric production was concentrated in the Alps of Savoie and Dauphiné. The average yearly capacity in that region was estimated at some 800 million kWh; the actual production, however, fell notably below that figure since, through lack of means to adapt production to consumption, large volumes of available water were discharged.

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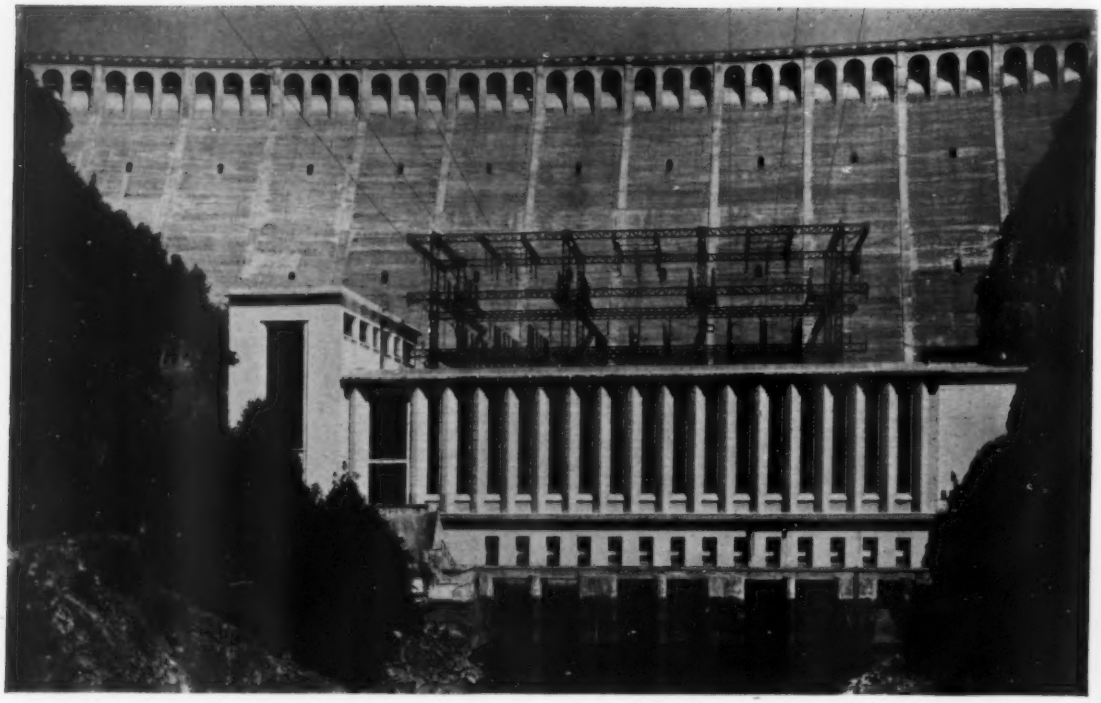


Fig. 2. Sarrans dam and power station (1934) on the Truyére containing three 34,000 kW sets operating at a head of 90 m.

Fig. 3. Development of transmission network 1930

rapidly. Annual capacity grew to 2,300 million kWh in the Alps; at the same time the proportion of distributed energy increased to 40 per cent. of the total output. In the Pyrénées, too, water power was being harnessed — the capacity in 1914 was about 600 million kWh; one-third being distributed and one-fourth supplied to the Compagnie des Chemins de Fer du Midi, which had initiated in 1910 a progressive scheme of electrical rail traction. The Massif Central was also producing at the rate of 300 million kWh per annum, almost the whole of the output being distributed.

The maximum power of the sets at that time was about 3,000 kW, and exceptionally reached 5,000 kW. Some stations were equipped with several units so that the total power in some cases exceeded 10,000 kW; it was, however, the exception. The most powerful of all was the Ventavon plant, on the Durance, with 28,000 kW produced by six units; next came l'Argentière, also on the Durance and one of its tributaries, with 25,000 kW and 25 d.c. generators. Those two plants were put into

operation in 1909. The highest utilized head of water was in the Pyrénées at Orlu where the fall was 950 metres. That station, which began working in 1910, might be regarded as the prototype for seasonal storage stations. The reservoir was a mountain lake, the capacity of which was increased by a dam of moderate height.

The Queuille plant, in the Massif Central, built in 1905, with 25 metres of gross head of water, was the first and, although small, very typical of power stations erected at the foot of a barrage (without headrace) where the head is wholly created by the damming of water. Many and much more impressive stations of this type were to be built in this area.

At Tuilière (16,000 kW, nine sets), on the Dordogne, built in 1908, was the perfect example of a low-head station, implanted in the very bed of the river in the trail of a mobile dam.

During the First Great War, projects, hampered at first, were continued for the supply of electricity to the armament industries; but fewer plants were built for distribution purposes. In 1918 the yearly average capacity, in billions of kWh, was as follows:

	Alps	Pyrénées	Massif Central	Others	Total
Self-supplying Industries	1·7	0·55*	0·05	—	2·3
Distribution	1·0	0·25	0·30	0·15	1·7
Total	2·7	0·80	0·35	0·15	4·0

* 0·25 of which for electrical rail traction

The actual output was probably in the region of 2·5 billion kWh per annum.

During the period 1900—1918 local networks of some extent were laid, and even regional networks for high-voltage transmission at distances over 100 km. The Moutiers-Lyons line, d.c. series, Thury system, has been in operation since 1906. From two generating stations on the high water of the Isère and the Doron de Bozel, it supplied the network of the Eastern suburbs of Lyons at a distance of nearly 200 km. It was in use until 1936. Operated by the Société Générale de Force and Lumière this network was also fed with a.c., 50 cycles, at 45 kV from the Grenoble region, 130 kilometres away. The regions of Vienne and Valence (100 kilometres apart) were supplied at 26 kV from a water-fall in the Vercors mountain range, about 30 kilometres away from the main transmission line, Vienne—Valence, with an emergency thermal station at Romans on the main circuit.

Special mention must be made of the Dauphiné—Centre 60 kV line, laid in 1910, which supplied the St. Chamond and St. Etienne area from the hydro-electric installations of l'Eau d'Olle (a tributary of the Romanche) near Grenoble. Small local stations on the

Fig. 4. Brommat underground station on the Truyére containing six 28,000 kW units under a head of 250 m.

Fig. 5. Development of transmission network 1935

Fig. 6. Dissorte dam impounding a usable reserve of 40 million cu. metres, representing 130 million kWh

Fig. 7. Development of transmission network 1939

Lignon and the Loire also contributed to the supply of the St. Etienne region. Thus was anticipated the inter-connection between the very different hydrological systems of the Alps and the Massif Central.

There was also the important 25-cycle network of l'Energie Electrique du Littoral Mediterraneen which spread over almost the whole of Provence, between the Rhône and Italy. Its main sources of power were the two hydraulic plants of Ventaton (20,000 kW, 1909) and of la Brillanne (10,000 kW, 1908) on the Durance and the thermal plants of Marseilles and Nice.

In short, at the time of the 1914-18 war, besides electro-chemistry and electro-metallurgy plants fed on the spot, large distribution networks had been developed, and were supplied partly by sources of power more than 100 kilometres away from the load consumption centres. Most of the networks were isolated from one another; but they were sometimes partly fed by the same generating stations, the outputs of which might be directed in varying proportions to one or the other. Self-supplying electro-chemistry plants

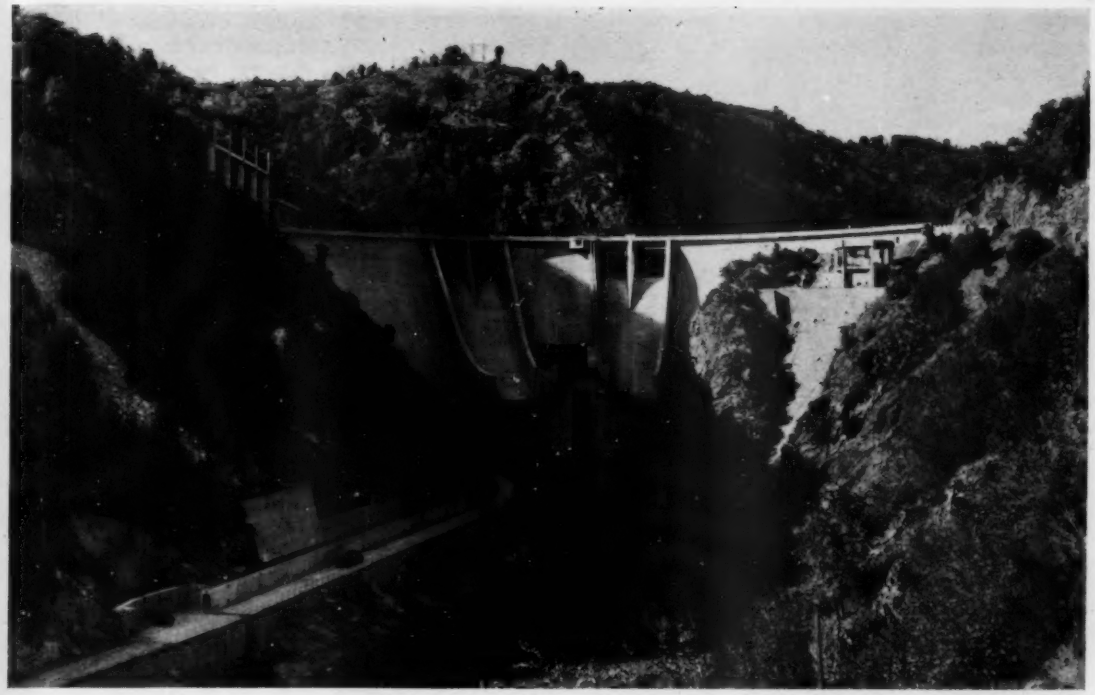
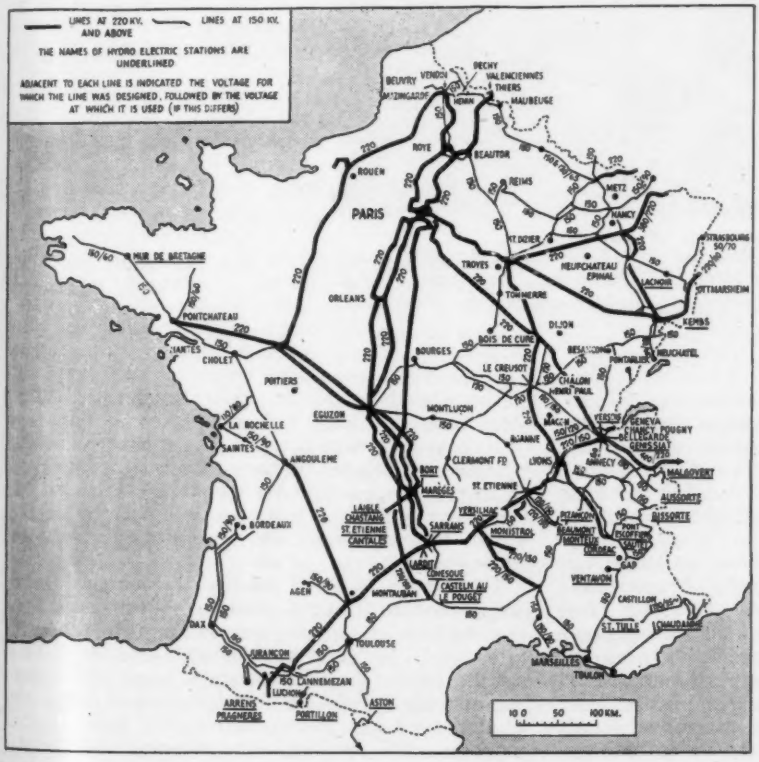


Fig. 8. l'Aigle dam and power station (1947-50) on the Dordogne containing three 50,000 kW sets at a head of 80 m.

Fig. 9. Development of transmission network 1947



and power stations built solely for distribution purposes also began to exchange energy.

Some reservoirs were then being built for exclusive use at peak periods—as we have seen a storage basin for seasonal regularization had been built in 1910 at Orlu in the Pyrénées—but much power was still being lost through the lack of suitable adjustment of output to demand.

Generator sets were not yet large enough, but some stations had many of them.

Period 1918-1931

Immediately after the First World War the industry regained its regular rate of progress, its capacity increasing from 4 to 10 billion kWh between 1918 and 1931.

The period was characterized by the considerable expansion of distribution systems and the laying of regional 150 kV networks.

In 1926 there existed a 120 kV line (later brought to 150 kV) between the Lyons region and the headwaters of l'Isère; a 120 and 150 kV link from the lower Isère to St. Etienne and Roanne; a 120 kV connection from Chancy-Pougny, on the Rhône (near the Swiss

Fig. 10. Valley head, Portillon, containing a 40,000 kW set operating under two alternative heads ranging from 1,100 to 1,350 metres. A pumping station is located at 2,250 metres above sea level to transfer some of the lower-head water to the high-head reservoir

border) to the Creusot area; a main 150 kV transmission line along the western half of the Pyrénées range, collecting the outputs of generating stations in the region, linked Bordeaux and Toulouse, via Dax, Pau and Lannemezan, and fed the main centres as well as the electric railway system of the Compagnie du Midi.

In 1929 the 150 kV systems of the Northern Alps and of St. Etienne—Roanne—Montluçon were linked by a line — St. Etienne—Givors—Grenoble. Two important interconnected systems were thus operating at 120 and 150 kV, one spreading between the Northern Alps and Lyons, St. Etienne, Roanne, Montluçon—the other in the Pyrénées (see Fig. 3).

During that period generator sets increased greatly in capacity: 5,000 kW became the standard unit and 10,000 kW was about the maximum. Among the larger stations built at the time, Eguzon, on the River Creuse (six sets of 10,500 kW under 55 metres of head, vertical axis turbines) was a barrage plant, which has been in operation since 1926. The dam (loaded type — 60 metres height — 300 metres top length) was the most important in the country at the time; the reserve of water, however, was only sufficient to allow a weekly feed. Vertical sets were as yet few in number and mostly used in low-head plants. Among them was Chancy - Pougny (1925), equipped with five 6,800 kW generator sets using a flow of 100 cubic metres per second under 8·90 metres of head. Pizancon (1931) was the first low-head modern plant in France, with four vertical groups of 10,000 kW (120 m^3/sec., 10·70 m. head), two generators of which were actuated by fixed-blade propeller turbines and two by variable-pitch bladed Kaplan turbines.

These few examples show that the number of sets in the important power houses of the time was from three to six—fewer than before 1918 because of the increase in unit power.

A larger proportion of plants had facilities for daily or weekly storage. The Eguzon station, for instance, whose peak output was 63,000 kW, only supplied a yearly average of 100 million kWh—*i.e.* just over the equivalent of 1,500 hours a year at maximum power. Some seasonal adjustment of production was also obtained through storage. The only important dam was that of the Chambon, on the River Romanche (1929); other reservoirs were mountain lakes in the Alps (la Girotte, les Sept-Laux) and particularly in the Pyrénées (Artouste, Estaens, Oredon). By 1930 existing reservoirs stored about 4 per cent. of the mean annual output but none was located in the Massif Central, where dams were mostly used to create the head.

The growth of both available power and actual output of hydro-electric plants is shown in Fig. 11. The wastage of water decreased from 40 per cent. to about 15 per cent. between 1923 and 1930. This was the result of the development of larger production-consumption systems and the provision of means for regularization and feeding. After 1930, however, the economic crisis resulted in the lowering of electricity

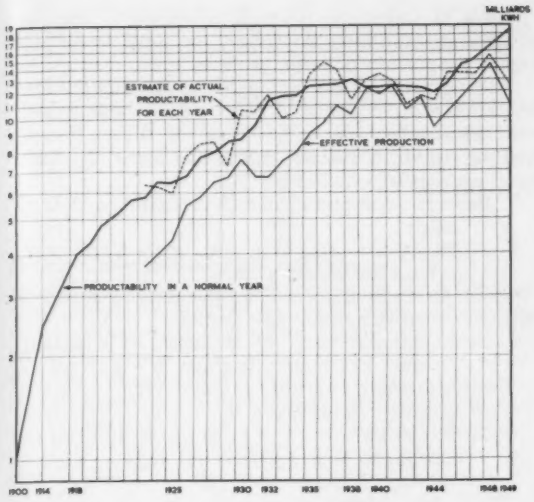


Fig. 11. Variation of production and productability in a normal year (semi-logarithmic scale)

consumption and a large surplus of unused hydraulic energy.

Period 1932-1938

The year 1932 marked an important stage in the development of French water power. Two very large plants were then put into operation, which far surpassed former installations and were the forerunners of the vast projects undertaken since. They were the underground power station of Brommat on the Truyère, in the Massif Central (later associated with the power house of Sarrans at the foot of a dam, which was put into operation in 1934), and the station of Kembs on the Rhine. Their generator sets were three times more powerful than those previously working in France; 25,000 kW at Kembs (propeller and Kaplan turbines absorbing 190 m³/s, under 16·70 m. head); 28,000 kW at Brommat (Francis—14 m³/s, 250 m. head); 34,000 kW at Sarrans (Francis—44 m³/s, under 90 m.).

More important still, as the plants had as many units as previous installations (six at Kembs and Brommat, three at Sarrans) their total output was considerable. The Brommat—Sarrans group produced annually a billion kWh and its maximum power was 270,000 kW. Corresponding figures for Kembs were 900 million kWh and 150,000 kW. Together they supplied about 15 per cent. of the peak output and 12 per cent. of the total annual consumption of the whole of France. It should also be emphasised that the storage capacity at Sarrans represented 200 million kWh. Such new projects had to be conceived on the national rather than the regional scale.

Three other large plants put into operation in the course of that period must be mentioned:

Mareges, barrage-foot type on the River Dordorge (Massif Central)—four generator sets of 35,000 kW —60 m³/sec. per unit, under 70 m. of head.

Sautet, barrage-foot type on the River Drac (Alpes) —six sets of 11,500 kW—15m³/sec. under 93 m. of head.

Bissorte, high-head station on a tributary of the Arc (Alpes), with a storage of 130 million kWh capacity—three sets of 23,500 kW under 1,100 m. of head.

Exploitation of these projects was made possible by the progress in high tension transmission techniques.

The Brommat — Mareges — Eguzon — Paris and Kembs—Paris lines, put into operation in 1932 were the first of the 220 kV transmission system. Between 1932 and 1935 the regional 150 kV South-West and Centre—Alpes grids were linked up and the combined system, to which a main to Marseilles was added, was connected with the Brommat—Paris and Kembs—Paris 220 kV lines—the latter being linked with the 150 kV thermal grid of the North-East.

Between 1935 and the eve of the war the pattern was hardly altered; but the national grid was noticeably strengthened. The linking of the 150 kV system was completed by the joining up of the west country network; the Brommat—Paris 220 kV line was doubled (see Figs. 5 and 7).

The former differentiation between various categories of producers had largely disappeared with the development of the national grid. Distribution companies, the railways and electro-chemistry industrialists contributed to the laying of 150 kV and 220 kV lines. The latter began to erect storage power stations, detached from the plants themselves, for the exclusive supply of alternating current at 50 cycles to the transmission network. At the same time electro-chemistry and electro-metallurgy plants drew power from the grid and no longer depended on local supply.

This period was an important one in French water-power development, marking as it did the beginning of the general linking up of regional systems with the national grid. Fig. 11 shows, however, a slowing down of the rate of increase of the production capacity. In 1931 and 1932 the world economic crisis had resulted in a steep fall of energy consumption in France (from 17 billion kWh in 1930 to some 15 billion in 1932). Water-power projects undertaken were carried out and put into operation between 1932 and 1935, bringing the production capacity from 9·5 billion kWh in 1931 to 11 billion in 1932 and 12·5 billion by the end of 1935. But, because of the crisis, no new important works were started from 1932 onwards and the capacity hardly increased between 1935 and 1938 (from 12·5 to 13 billion kWh).

After 1932, however, consumption grew again quickly and the demand (including losses) reached 21 billion kWh in 1938. This growth of demand could only be satisfied from existing means of production thanks to the linking up of all grids and to the better use of hydraulic resources through the improvement of seasonal reserve capacity (6 per cent. of mean availability in 1938); discharge losses which had reached almost 50 per cent. of available resources in 1932 because of the crisis were reduced to less than 10 per cent. in 1938. On the other hand, over this period water power played an increasing part in the global output; from 40 per cent. in 1925, it exceeded 50 per cent. in 1935—up to 55 per cent. in 1937 and 1939. In 1938, however, production was fully absorbed and it was urgent to launch a new programme of capital investment and construction: this was done by agreement between Government and private industry representatives. A large proportion of the projects were of moderate size, so that they could be carried out quickly; but war and the

occupation of France slowed down the work already undertaken and delayed the new projects.

The War and after

Although new installations were put into operation during the occupation, the total capacity of French power stations fell, through war damage, to 12 billion kWh in 1944. Reconstruction was started after the liberation; the 1938 programme was resumed and extended in the framework of the capital investment "Monnet Plan." The bill nationalizing the electricity industry was passed in 1945 by the French parliament and Electricité de France became responsible for the carrying out of the plan. The harnessing of the Rhône river, however, remained within the province of the Compagnie Nationale du Rhône.

TABLE I

Region	Units in operation beginning of 1950	To be put in operation by end of 1954	Total
Massif Central .	4·4	2·0	6·4
Pyrenees ...	3·6	1·0	4·6
Alpes du Nord .	4·7	2·8	7·5
Alpes du Sud .	1·2	0·3	1·5
Rhone . .	2·0	2·2	4·2
Rhine . .	0·8	0·7	1·5
Others . .	1·3	–	1·3
Total . .	18·0	9·0	27·0

New units put into service between 1945 and the end of 1949 represented a mean annual capacity of almost 4·5 billion kWh (1·4 of which was at Génissiat, on the Rhône). Thus the total average capacity at the beginning of 1950 was 18 billion kWh per annum.

In spite of the continued use at full capacity of the old thermal equipment, very hard worked in the abnormal conditions of the occupation, and now decrepit, despite the erection of new and important thermal plants, production did not yet match the demand for electrical energy which had increased by more than 50 per cent. above its 1938 level.

At the completion of the actual programme, forecast for the end of 1954, water-power resources will supply an extra 9 billion kWh per annum (50 per cent. of the present capacity). It may be expected that the shortage of energy, experienced in recent years, will soon be overcome.

This review of the development of the French water-power industry can best be concluded by a summary of its structure, as it now exists and will exist in 1954.

The hydro-electric capacity in the various large hydrological regions is given in billions of kWh in Table I.

Table II shows the position according to the size of stations and illustrates clearly the trend towards a higher proportion of large projects.

The most remarkable among those recently put into operation are the Génissiat fall, on the Rhône (which was described in an earlier issue of *Water Power*) and the station of l'Aigle, on the Dordogne, the main specifications of which are:

Barrage—compound loaded-vaulted type of 95 m. height.

3—50,000 kW sets (75 m^3/sec. under 80 m. head) —base for a fourth set.

More powerful units will be installed in plants to be put into service in the near future:

3—85,000 kW sets, 70 m. head, at Chastang, on the Dordogne (barrage 85 m. high — compound loaded-vaulted type — reserve capacity 38 million m^3).

2—90,000 kW sets, 110 m. head, at Bort, on the Dordogne (barrage 120 m. high — loaded-vaulted / Reserve 400 million m^3, *i.e.* 270 billion kWh.

4—72,000 kW sets, 750 m. head, at Malcovert, on the Haute-Isere.

Upstream of the latter project, the vaulted-dam of Tignes, is being erected; it will be 160 m. high above the river bed (180 above foundations), and will store a reserve equivalent to 600 million kWh.

The total sum of energy stored in large reservoirs, which now amounts to 1·4 billion kWh—*i.e.* 8 per cent. of the mean annual capacity of output—should be brought up to 3·4 billion by the end of 1954 (*i.e.* 12·5 per cent. of mean total per annum). This stresses the importance of water regulation.

The systematic increase of unit power of generating sets and the search for reservoirs of large energy value have sometimes led to an appreciable alteration in the general concept of projects. A few striking features of this evolution will be given later.

The present period is thus characterized by a new stage in the increase of unit power, the maximum of which is doubled as compared with pre-war. Large projects, on the national scale, take precedence over small and medium installations, with a marked trend towards seasonal regulation equally conceived on the national plane. This, of course, has only been possible because of the attendant development of the transmission network (150 and 220 kV) which has been extended from 9,000 km. in 1938 to 14,000 km. now and will spread over 18,000 km. in the next five years. Some lines are already designed for the ultimate transmission of power at 380 kV.

TABLE II

Mean capacity per annum in million kWh	Number of Plants			Total mean annual producibility per category (in billion kWh)		
	In operation beginning of 1950	To be put in operation end of 1954	Total	In operation	To be put in operation	Total
Less than 10 . .	1·300	—	1·300	0·5	—	0·5
10 to 100 . . .	225	18	243	8·5	1·5	10·0
Over 100 . . .	40	19	59	9·0	7·5	16·5
Total . .				18·0	9·0	27·0

For the reproduction rights of the photographic illustrations which appear in this and the subsequent portion of this article we are indebted to Photo Industrielle A Baranger.

(To be continued)

A Study Tour in the Alps

In the second part of this article Dr. Charles Jaeger describes further features which attracted his attention during a recent inspection of underground hydro-electric stations in the French and Italian Alps.

Italian Underground Power Stations

Nowadays there is a definite trend in favour of underground stations. Among the many reasons for this development it may be mentioned that an underground station is sometimes the only solution which suits the contour lines if the use of large surge tanks is to be avoided. Cost calculations are often in favour of the underground alternative, which is usually also the best for turbine governing, especially for medium head plants. [6, 10, 11.]

One of the main objects of the author's journey to Italy was to gain an insight into the conditions prevailing in that country and the type of underground station being built in the Italian Alps and to compare them with Swedish and Swiss types of station.

It is well known that the success of the Swedish and, to a large extent, of the Swiss underground power schemes, is due to a new tunnelling technique using light drills and pushing the work forward at high speed with the use of mechanised equipment and well-trained teams.

In Italy the Edison Company do not use the Swedish tunnelling methods, and have only very recently introduced the American "jumbo" technique on one of their sites. This is too short a period to afford any kind of comparison with the more conventional methods previously used.

Nevertheless, in Italy as in other countries, there is a definite trend in favour of the underground station. This trend seems to be independent of the contracting methods and the contractors' plant used, provided the methods are adapted to the prevailing wage levels. Italian experience shows definitely that the success of underground power stations does not depend on the use of Swedish tunnelling methods, as was generally thought.

The interiors of the various Italian underground stations are very simple and several of them remind one of British practice, e.g. Galloway.

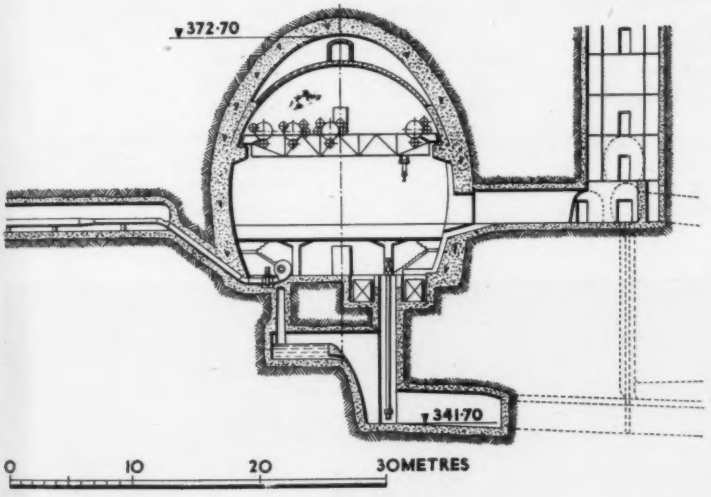
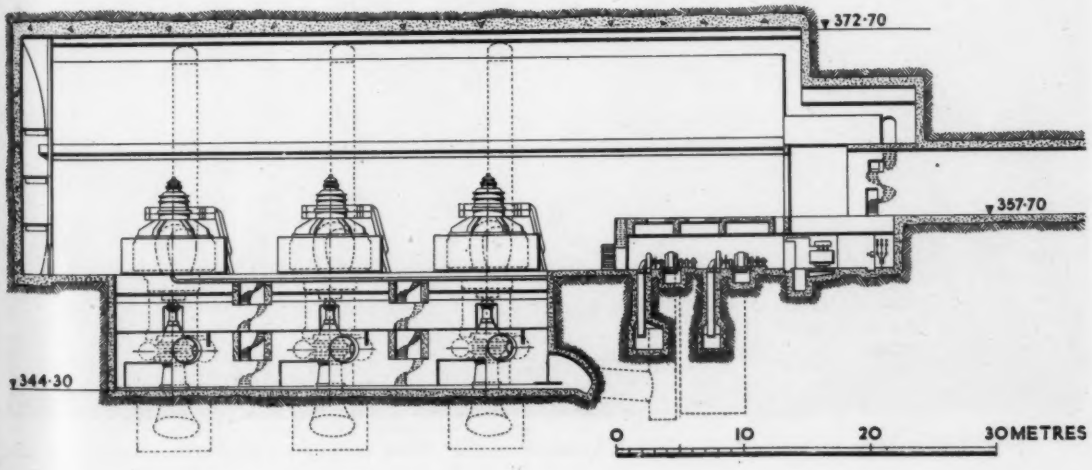


Fig. 8(a). Santa Guistina underground power house. Transverse and longitudinal sections



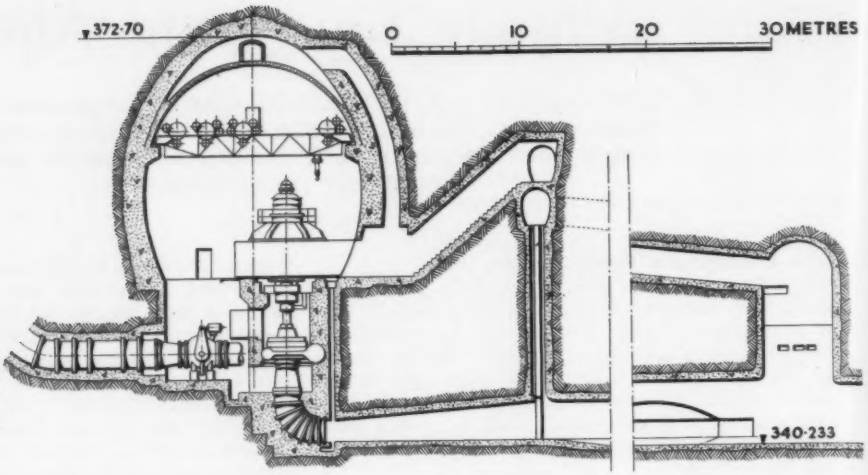


Fig. 8(b). Santa Guistina underground power house — cross-section

Underground stations in the Italian Alps were adapted to rock conditions quite different from the Swedish stations, which are all built in hard Swedish granite. In Italy, underground stations are built in limestone, Dolomite or marl. Some of these rocks are impervious, others not; some are hard, others are plastic and internally stressed; many are fissured. In all cases the methods of construction were simple, beginning with the excavation and concreting of the arched roof.

Concerning transformers, the engineers of the Edison Company give the following ruling: if the cable length is less than 250 m., then the transformers should preferably be out of doors, if the cable length is more than 350 m. it is usually cheaper to arrange the transformers underground.

Particulars of some Italian Underground Stations

Santa Massenza I (Society Idro-Elettrica Sarca-Molveno Edison partnership)

Head	530 – 610 m.
Discharge ...	2 × 37 = 70 cu. m. per sec. (2 pressure pipes)
Generating Plant	4 × 70,000 kVA (horizontal-shaft 2 × 35,000 kVA impulse wheels) 1 × 5,000 kVA 1 × 1,000 kVA

Fig. 9. Sonico Cedegolo power development on the River Oglio — The Foglia Dam

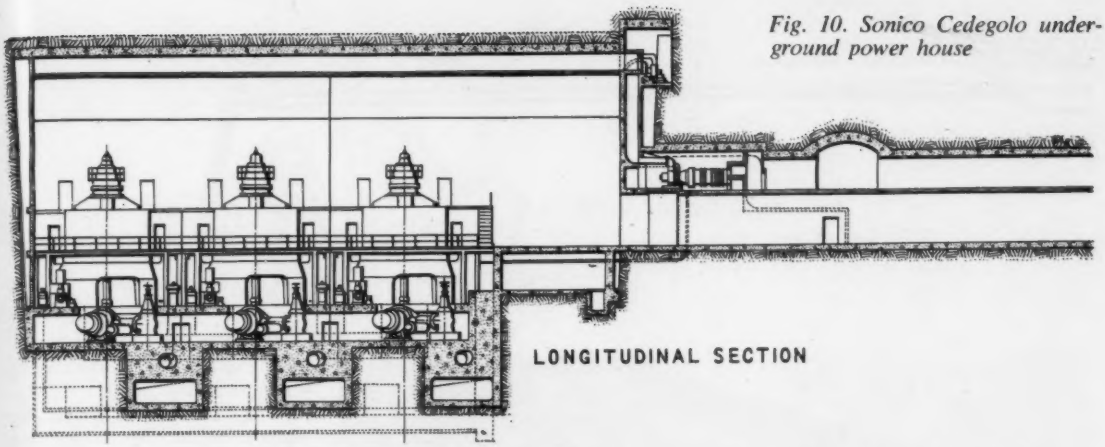


Fig. 10. Sonico Cedegolo underground power house

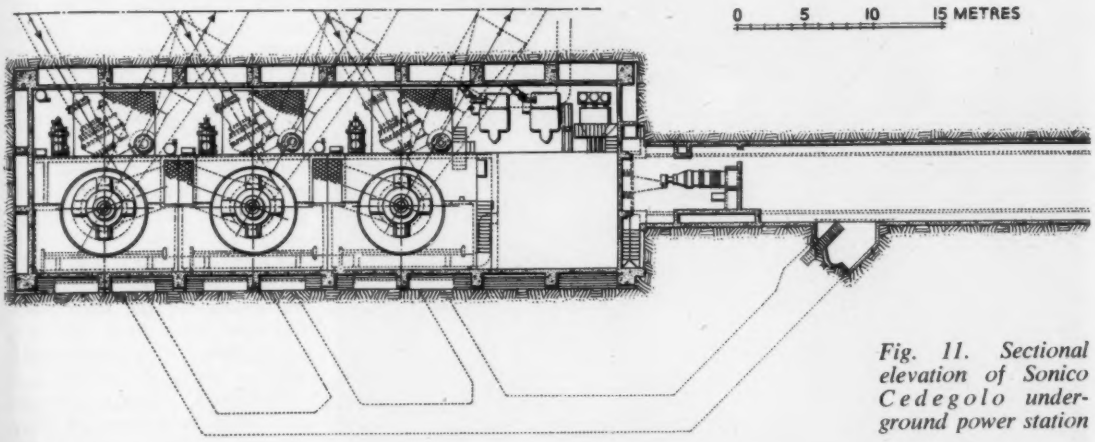


Fig. 11. Sectional elevation of Sonico Cedegolo underground power station

Santa Massenza II (projected)

Generating Plant ... 1 × 25,000 kVA
1 × 5,000 kVA

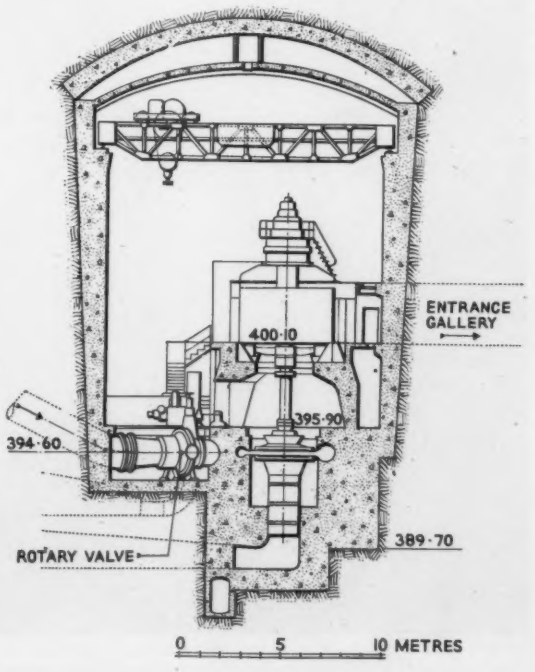
also, 2 pumps with 15 cu. m. per sec. total discharge. The power house is excavated in Dolomite limestone as also is the housing for the transformers, the main dimensions being:—

length	...	...	197 m.
width	...	...	25 m.
height	...	...	28 m.
length valve gallery	...		170 m.
length access gallery	...		350 m.
length tailrace gallery	...		145·20 + 552 m.
width of tailrace	...		6·50 to 7·00 m.

A space of 0·50 m. is left between the situ rock and the concrete of the power house. The rock, as at the Lavey underground power house in Switzerland, is not supported.

The pressure tunnel has a diameter of 4·80 m. and is 5,174 m. long with a slope of 3·5 in 1,000.

The two penstocks are steel-lined pressure galleries 2·70 to 2·50 m. dia. and 35 m. apart, with a gradient of 1 in 0·85. This is a steeper inclination than is used for the Swiss Innertkirchen steel-lined pentsock and more than is usually used for other Italian penstocks; it has been chosen in order to prevent the excavated debris from sliding but at the same time to facilitate the rolling of any blocks when clearing the tunnel.



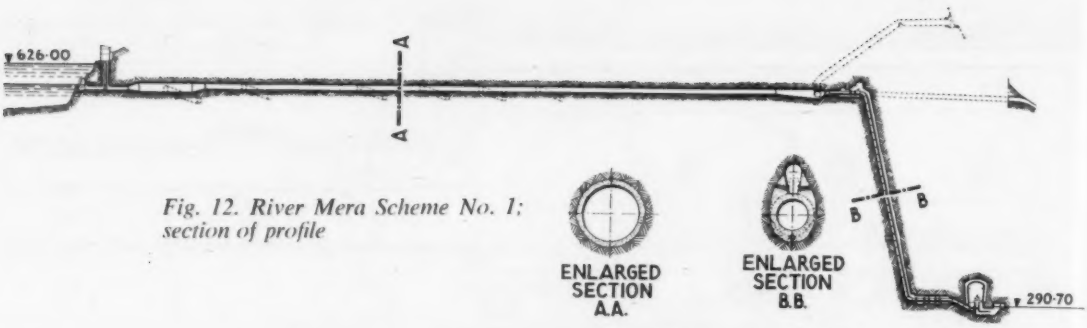


Fig. 12. River Mera Scheme No. 1: section of profile

Fig. 13. Villa di Chiavenna spillway dam, River Mera

The stresses in the steel lining were permitted to be 1,800 kg. per sq. cm. when neglecting support from the rock, and 1,000 to 1,100 kg. per sq. cm. near the base. The figures usually taken for steel linings in Italy vary from 1,600 kg. per sq. cm. to 1,800 kg. per sq. cm. These are far less than the stresses allowed for the Innertkirchen steel lining in a penstock through very good gneiss, and for other modern plants and projects.

Professor Oberti did some experimental research work on the factor for the load transmission from steel to rock, which was dealt with theoretically as early as 1933 [8, 9] in Switzerland, Austria, Norway, but little is known of these efforts.

Santa Guistina Power Station

The leading data for this power station (Gruppo Edison) were given in connection with the description of the dam (Fig. 5). The pressure tunnel is in limestone and is lined with concrete, weak points being reinforced with ordinary reinforcing bars, and in some places with 40 mm. steel mesh (4 mm. steel wires).

The underground power house is in marl. As the limestone is fissured, it was preferred to locate the power house in impervious rock, despite possible pressure and strains that might develop in the plastic marl. The power house excavation is elliptical in shape (Fig. 8), and the concrete is laid directly against the rock; heavy horizontal struts have been inserted at the generator floor level to act as reinforcements against possible pressure from the plastic rock.

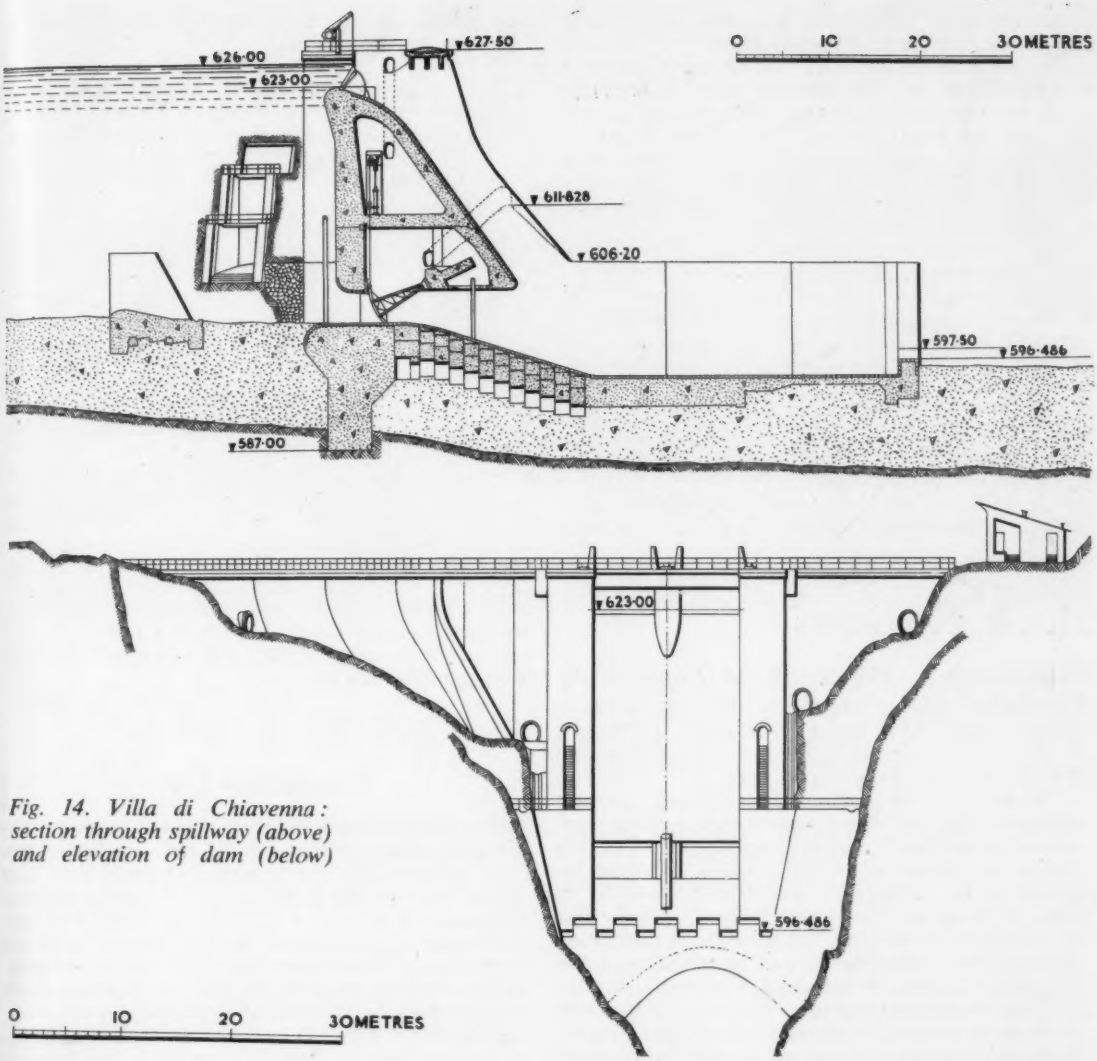


Fig. 14. Villa di Chiavenna: section through spillway (above) and elevation of dam (below)

The concrete looks absolutely tight, and so does the upstream part of the access tunnel. The downstream part shows some leaks because of the insufficient overburden. The power cables are carried through the upper part of the access tunnel.

Sonico-Cedegolo Plant. Val Canonica (Gruppo Edison)

The main intake is on the river Oglio at a level of 637·55 m. O.D. A maximum discharge of 24 cu. m. per sec. runs through the free-flow tunnel, 13,151 m. in length, to the small Poglia pond which has a storage capacity of 450,000 cu. m., a maximum water level of 630 m. and a minimum water level of 610 m. O.D.

The Poglia dam (Fig. 9) is of the buttress type which has many points of correspondence with the Dixence dam; the downstream and the upstream faces are both inclined, the structure being divided into large independent cells with two buttresses each. It contains 35,000 cu. m. of concrete. Spillways are built at each side.

The penstock consists of a 195 m. long pipeline and a vertical steel-lined shaft. The power house is underground (Fig. 10) and operates on a total head of 243 m. There are three vertical Francis turbines driving three 24,400 kW generators; the yearly output of the plant is estimated at 202,000,000 kWh.

This power house is built in limestone and, as there is no rock pressure to be feared, the side walls of the excavation are vertical. The concrete is laid directly against the rock walls, as shown on the cross section in Fig. 11.

No. 1 Station, River Mera, near Chiavenna (Gruppo Edison)

This station (Fig. 12) is worthy of note because of the Villa di Chiavenna dam (Figs. 13 and 14) the cross sections of which remind one of the Verbois dam with its tilting gates at the top and sector gates at the base. This Italian dam is built above a horizontal arch spanning a deep gorge.

The power house is underground and very similar to the Cedegolo station. It was the only station seen

under operating conditions, the other three being still at different stages of construction.

The capacity of the Villa di Chiavenna reservoir is 1,100,000 cu. m. The pressure tunnel is 7,108 m. long, the maximum discharge being 20 cu. m. per sec. and the head 335 m. The power house is equipped with three vertical Francis turbines each connected to a 27,000 kVA alternator, the whole yielding 202,000,000 kWh per annum. The transformers are situated in the open.

The three underground stations at Mera, Oglio and Santa Guistina are all of the same type, the general arrangement of the sets being similar to that at the much bigger power house at Loch Sloy in Scotland but adapted to underground design. The cross sections and photographs are self explanatory.

These more recent underground power stations belonging to the Gruppo Edison can be compared with those of the Società Adriatica di Elettricità, Venezia,[5] and others.[13]

The photographs and plans in connection with this article will give an idea of the Italian technique in dam construction, other than arch dams. Also sufficient details are given to illustrate Italian skill in designing the intake works.

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Book Reviews

Molesworth's Handbook of Engineering Formulae

(34th edition). Edited by A. P. Thurston, M.B.E., D.Sc., M.I.Mech.E., F.R.Ae.S., F.C.I.P.A., E. & F. Spon Limited, 15 Bedford Street, London, W.C.2. 1,672 pp. Price 32s. 6d. net.

"Molesworth" is such a household name amongst engineers that the mere announcement of a new edition constitutes a sufficient introduction. The first edition was published in 1862, and it has been regarded as the "Engineer's Bible" throughout its 90 years of existence. The new edition fully maintains the Molesworth tradition, but it has been completely rewritten and re-illustrated, and its preparation has occupied six years. It is intended primarily for the civil and mechanical engineer, and provides him with an immense amount of detailed information on practically every branch of engineering with which he is likely to be concerned, including marine, railway and electrical engineering. We must confess to some surprise at the omission of a section on internal-combustion engines (except for half-a-dozen pages on fuels), especially as steam engineering is treated so admirably, but apart from this we have nothing but praise for the range of subjects covered and for the manner in which so much information has been condensed into the available space.

Lexique Technique Anglais-Francais

(English-French Technical Vocabulary), by Guy Malgorn. Published by Gauthier-Villars, quai des Grands-Augustins, 55, Paris, 1950, 8·3 in. × 5·3 in., 332 pp. Price (paper cover) Fr. 1,300.

Judging by the number of technical English-French dictionaries, vocabularies and glossaries which have been published in recent years, there must be a considerable demand for this kind of publication in France. Unfortunately the standard of quality is not particularly high, and this latest addition is certainly no improvement. Not to mention terms which have never figured in any English or American dictionary, and words of general use for which a technical glossary is not the proper place, this "lexique" contains a few genuine howlers.

G.J.P.

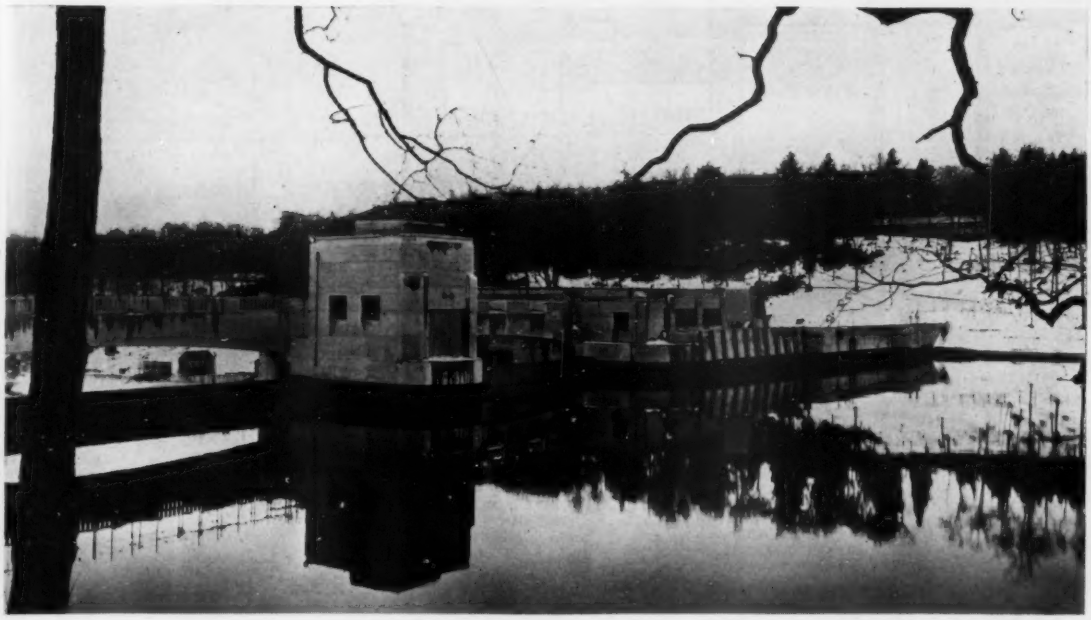
Insulating Oil

The British Standards Institution has recently published a revised edition of B.S.148, Insulating oils (low viscosity) for transformers and switchgear. The original edition was published in 1933 and dealt with six classes of oil, viz., A.0, A.10, A.30, B.0, B.10 and B.30, differing in allowable sludge limits and cold test temperatures. Experience has shown that while satisfactory performance in respect of freedom from sludge formation is provided in practice by oils meeting the sludge test limit for Class B oils, it is desirable to exclude oils of this class having a tendency to excessive formation of acidity. Such oils are accordingly excluded from this revision. Further, it is now considered unnecessary to provide a selection of oils having different temperature characteristics, and a maximum pour point of −25°F. (−31·7°C.) has been standardised as suitable for the majority of conditions.

The revised edition of B.S.148 is based largely on information supplied by the British Electrical and Allied Industries Research Association. Copies of this standard may be obtained from the British Standards Institution, Sales Department, 24 Victoria Street, London, S.W.1, price 6s. post free.

Guayabo Hydro-Electric Project

In connection with the article on Guayabo in the March issue, Mr. L. F. Harza, of the Harza Engineering Company, would like to point out that in line 14 from the bottom of the first column, page 99, the word "air" should be deleted. This refers to the water intake for the turbines and the word "air" must have blown in somehow.



Pitlochry—II

The Tummel-Garry project of the North of Scotland Hydro-Electric Board has reached a further stage by the commissioning of Pitlochry power station.

OUR previous article was devoted to the civil engineering work involved in the damming of the river Tummel at Pitlochry, and we will now describe the mechanical and electrical equipment of the Pitlochry generating station.

Power House

As already stated, the power house forms part of the dam structure, the intake, retaining wall, basement, and turbine spirals being in reinforced concrete, while the superstructure is structural steel framed with concrete walls faced with precast concrete blocks. The granite aggregate for these blocks has been carefully graded and the surface brushed to give a roughened texture, and by using two grades of aggregate a most attractive finish has been given to the building. A dignified entrance hall leads to well-appointed offices and to a spacious display room on the first floor from which a fine downstream view is obtained. Opposite to this room is an observation gallery commanding a general view of the turbine house, which is 105 ft. long by 45 ft. wide.

The power house intake is protected by trash screens from which the trash is lifted by rakes operated from an Ames Cresta Mills travelling winch and dumped into skips running on a narrow-gauge track. Owing to the large water flow required at the low head available, each of the two turbines is provided with two intake passages, which merge at the spiral. Normally the water has an uninterrupted run to the turbines, which are started-up and shut down by the guide vanes, but for maintenance purposes two 14 ft. 9 in. by 14 ft. Glenfield and Kennedy stop gates are available which can be lowered by a travelling gantry into the intakes of either turbine. Two hand-operated 26 ft. $10\frac{3}{8}$ in. by 7 ft. $6\frac{3}{8}$ in. Glenfield stop gates serve to isolate the draught tubes.

Main Generating Sets

The main generating plant at Pitlochry consists of two 7,500 kW sets. They are vertical machines running at 167 r.p.m. and comprise Metropolitan-Vickers alternators coupled to Kaplan turbines built by Glenfield and Kennedy Limited to the design of Boving and Co. Ltd.

Each turbine is designed to give an output of 10,900 h.p. at a net head of 42·5—47 ft., and a sectional elevation is given in Fig. 20. As already stated, the spiral casing is in reinforced concrete, and fixed stay vanes, built in during the construction of the station, support the upper part of the spiral on which the turbine cover is carried. The movable guide vanes are of cast steel and have rubber sealing strips at the line of closure to minimise leakage when

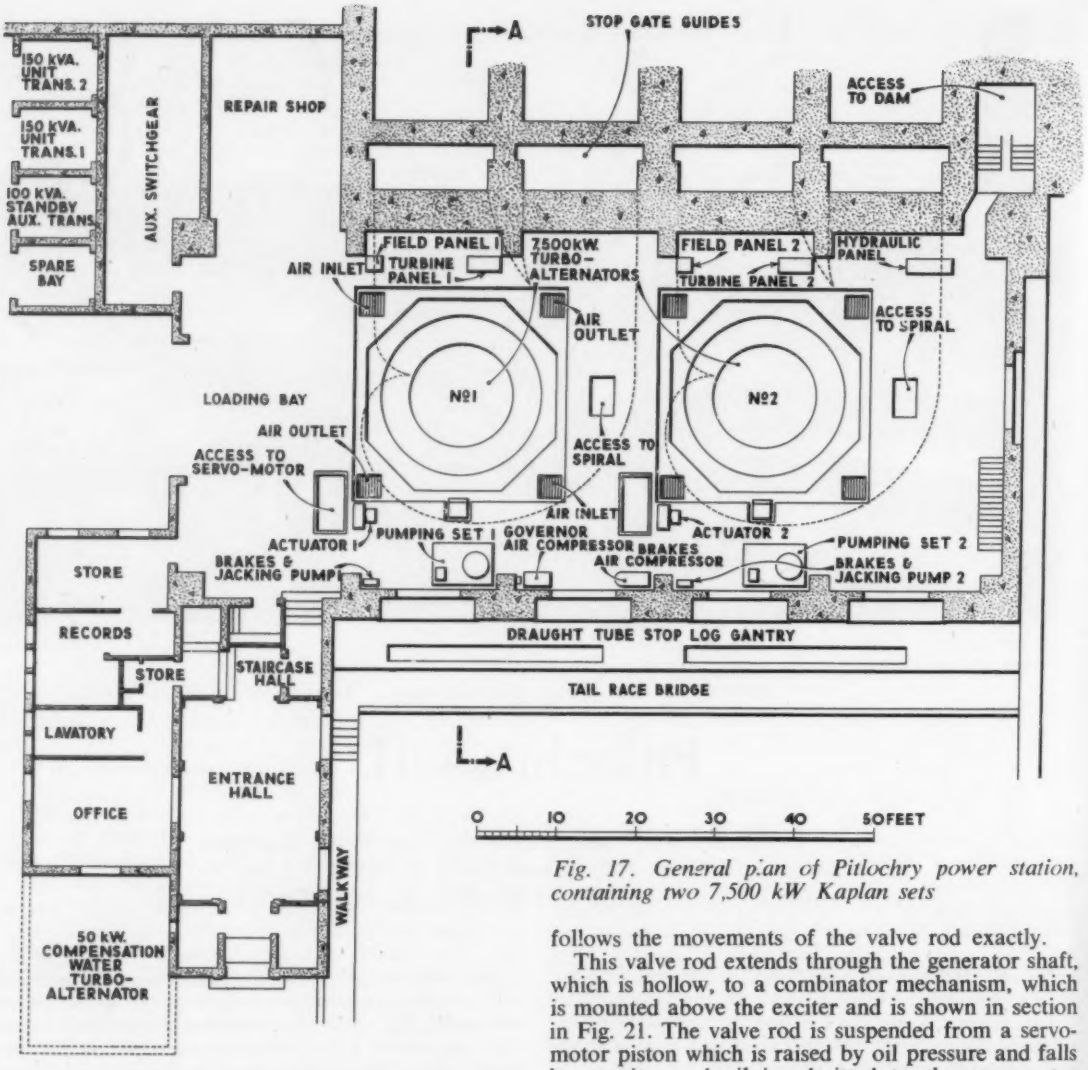


Fig. 17. General plan of Pitlochry power station, containing two 7,500 kW Kaplan sets

the turbine is shut down. The regulating ring to which the guide vanes are connected is supported from the top cover, which also carries the lower guide bearing for the main shaft, this being of the whitemetal-lined sleeve type with a self-contained lubrication system.

The turbine runner consists of a cast-steel hub on which are mounted four cast stainless-steel blades, carried on crankpin rings so that they can be swivelled to alter the blade angle. The pins on these crankpin rings project inwards and engage projections on a piston rod solidly connected to a piston working in a cylinder in the upper part of the hub, so that movement of the piston swivels the blades. Piston pumps are attached to the lower part of the main piston rod to flush all working parts with lubricating oil on each downward stroke, the amount of lubrication being therefore proportional to the amount of movement of the blades. Pressure oil to operate the main piston is controlled by a central valve rod, the ports being so arranged that the piston follows the movements of the valve rod exactly.

This valve rod extends through the generator shaft, which is hollow, to a combinator mechanism, which is mounted above the exciter and is shown in section in Fig. 21. The valve rod is suspended from a servomotor piston which is raised by oil pressure and falls by gravity, and oil is admitted to the servomotor by a pilot valve which is controlled by a floating link, one end of which responds to the position of the servomotor piston and the other to that of a cam moved by a linkwork in accordance with the position of the actuator governor. Movements of the actuator simultaneously control the main servomotor operating the guide-vane regulating ring, and the profile of the combinator cam is adjusted in accordance with test results to give the optimum relationship between guide-vane and runner-blade positions at all loads.

A sectional elevation of the actuator is given in Fig. 22. The centrifugal governor is driven by a permanent-magnet synchronous motor fed through a solid electrical connection from a permanent-magnet generator mounted on the turbine shaft, the number of poles of generator and motor being chosen so that the governor runs in step with the turbine but at a higher speed. Movements of the governor control a pilot valve, which is protected from hunting by means of a damping device; this pilot valve actuates a regulating valve which in turn actuates a servomotor

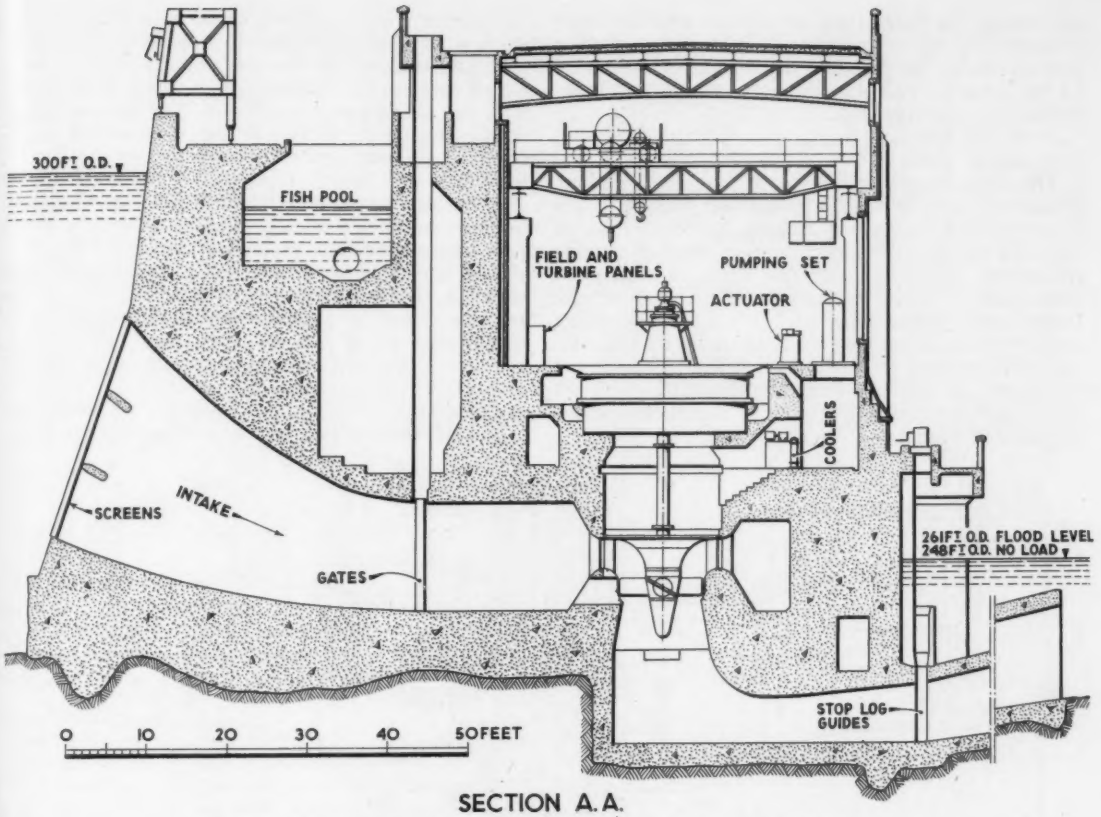


Fig. 18. Section through the power station on the centreline of one set

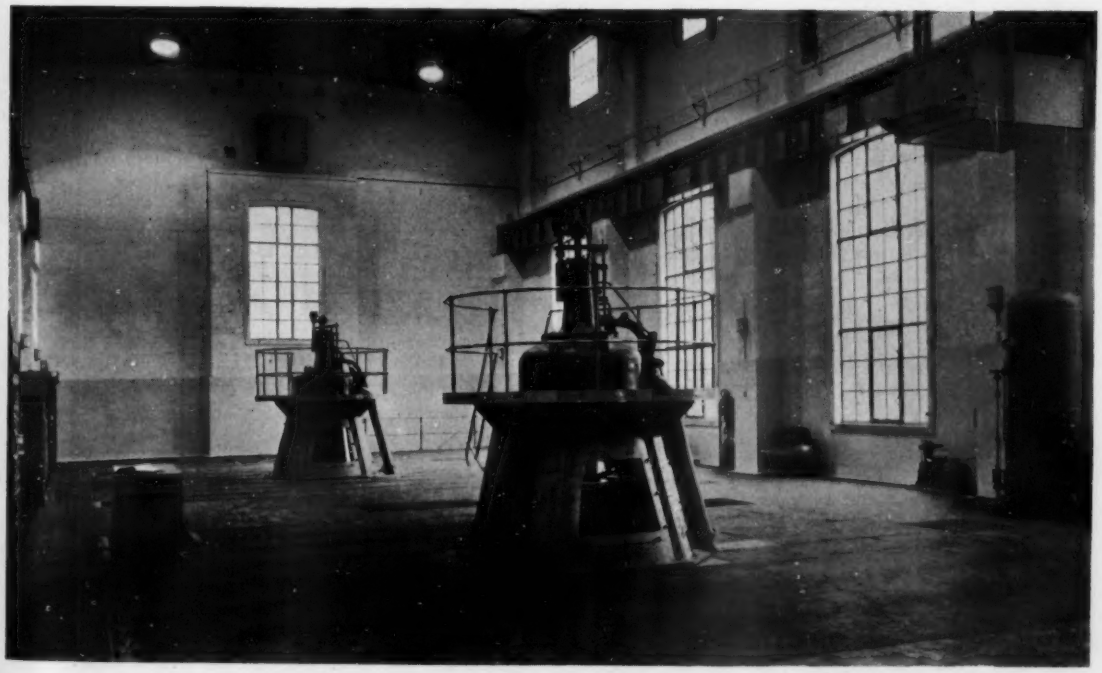


Fig. 19. Interior of the power house, showing the combinator assemblies of the two sets

controlling the guide-vane servomotor and the combinator cam. All hand controls for starting, stopping and regulating the speed of the turbine are mounted on the actuator, and electrical speeder gear and load-limiter are incorporated.

Alternators

The alternators were built by Metropolitan-Vickers Electrical Co. Ltd., and generate at 11,000 V at 0·9 power factor. The thrust bearing carries a load of 226 tons and is of the spring-mounted type. It consists of a collar, 5 ft. in diameter, carried on 16 whitemetal pads each of which is supported on a nest of pre-compressed helical springs, the assembly being housed in an oil well which is mounted on the concrete foundation by eight radial arms. An upper guide bearing registers with the outside of the thrust collar, and a lower guide bearing is mounted above the turbine runner.

The rotor is bolted and keyed to a flange on the shaft so that it can be lifted separately. It consists of a cast-steel spider around which is built a deep rim of overlapping segmental high-tensile steel stampings, the arrangement being such that the centrifugal stresses set up in the rim are not transmitted to the spider. Laminated poles are attached to the rim by tee-heads and double taper keys. The coils are of copper strip wound on edge, with asbestos insulation between turns and mica insulation to core, and the pole tips are specially shaped to reduce slot ripple.

The rotor weighs 65 tons and is designed to withstand a runaway speed of 480 r.p.m. It can be brought to rest by a set of eight brakes operated by compressed air at 200 lb. per sq. in. These brakes can also be used as jacks by supplying them with oil at 1,000 lb. per sq. in.

The stator is housed in a square pit and is of fabricated construction with a core built up of silicon-

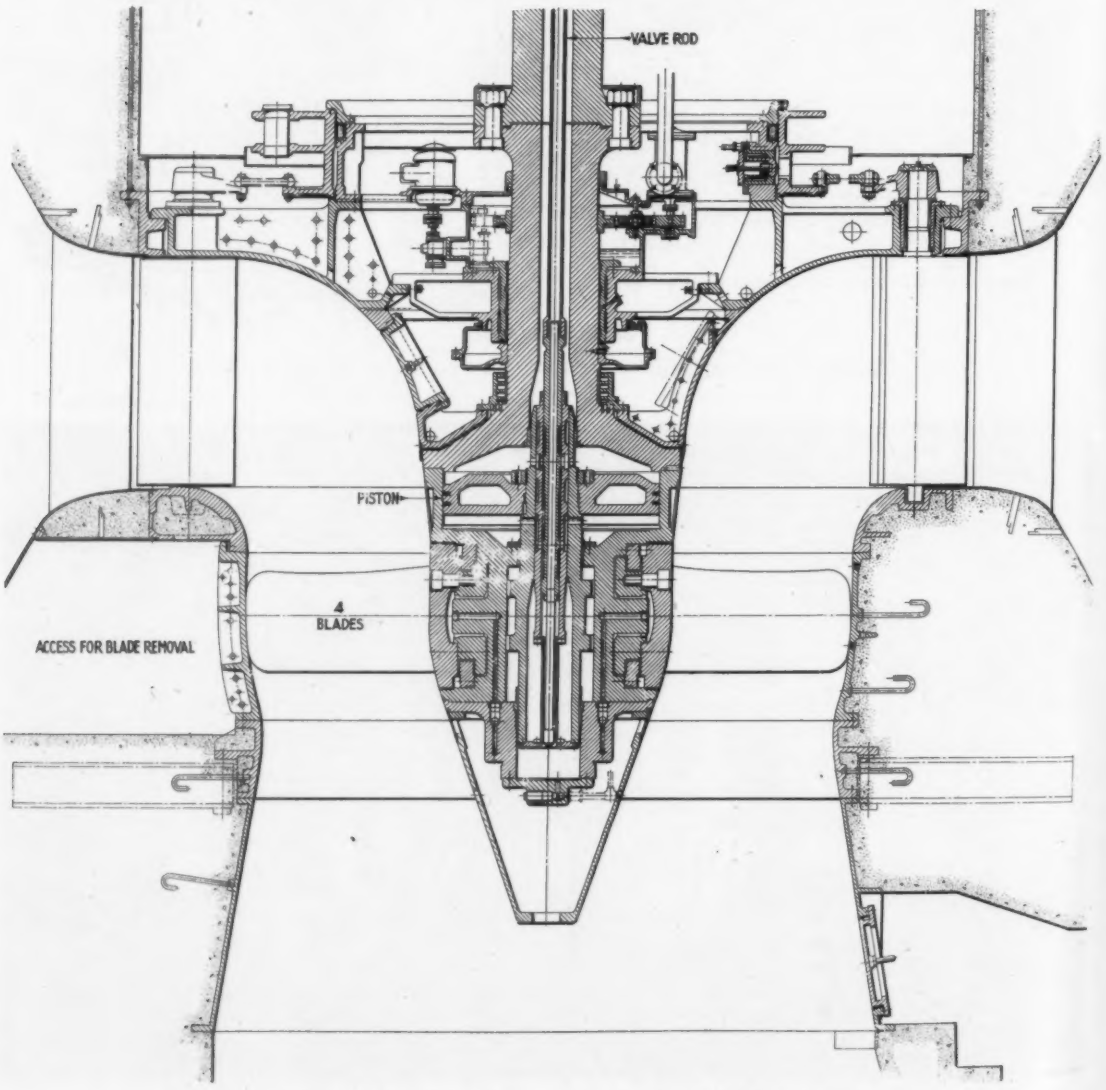


Fig. 20. Sectional elevation of one of the Boving Kaplan-type turbines

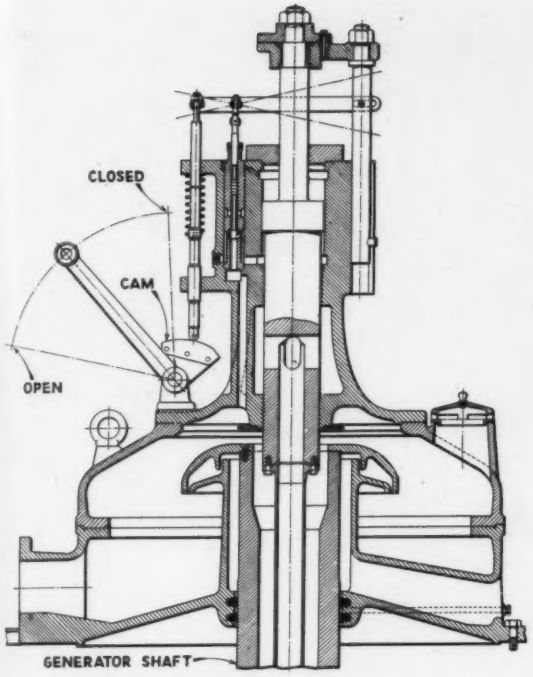


Fig. 21. The combinator mechanism

steel stampings. Preformed coils insulated with bitumen-mica silk taping are used to build up a two-layer winding. Closed-circuit air cooling is maintained by fans mounted on both ends of the rotor shaft, air coolers being mounted in the four corners of the stator pit and supplied with cooling water from the turbine spiral. To warm the station in winter, some of the hot air can be bypassed into the generator house, make-up air being supplied through dry-type filters.

Above the alternator are mounted a main exciter and a constant-voltage pilot exciter, the latter operating in conjunction with a Metropolitan-Vickers voltage regulator.

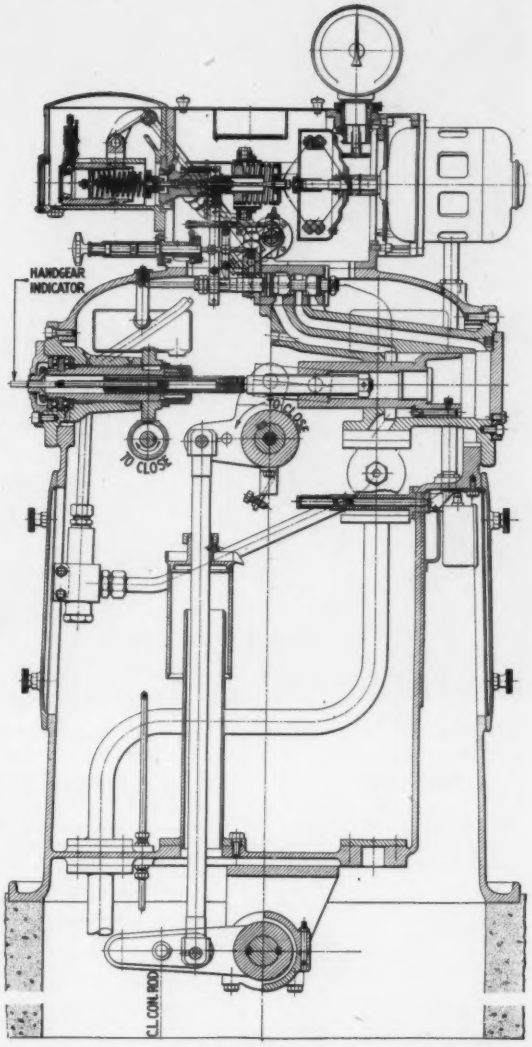


Fig. 22. Section through the actuator

Auxiliaries

As at Clunie a distinction is made between essential auxiliaries — those without which the main sets cannot function— and general auxiliaries, but the arrangement at Pitlochry differs somewhat for two reasons. In the first place, owing to the low head available, it is not practicable to use Pelton-driven auxiliaries; in the second, as there is no main switchgear at Pitlochry there is no call for a main battery, so that it is not feasible to have battery-driven auxiliaries.

Reverting to the essential auxiliaries, the main turbine-bearing oil pumps are gear driven from their respective turbine shafts. The alternator bearings are lubricated by separate pumps, and the alternator bearing pump and the governor oil pump for each turbine are supplied from a 150 kVA 11,000/415 V unit transformer feeding through a unit switchboard. A small standby governor oil pump is geared to each turbine shaft, sufficient merely for slow closure of the guide vanes if the supply from the unit transformers is lost due to an emergency shutdown. All other auxiliaries, which include the standby governor and turbine oil pumps, are supplied from a 415 V common service board, which can be energised either from the unit transformer or from a ring main from Tummel Bridge station. This ring main is independent of the Clunie/Pitlochry power system; it runs at 33 kV from Tummel Bridge to Clunie power station and thence at 11 kV to Pitlochry, where it feeds the town supply. It is connected to the station auxiliary supply through a 100 kVA transformer. The compensation-water set is also coupled to this circuit. It consists of a 50 kW Bruce Peebles induction generator driven by a Gilbert Gilkes and Gordon turbine.

To start either main set the unit board controlling the essential auxiliaries is connected to the common services board until the set is up to speed and the unit transformer energised. The unit board is then transferred to the unit transformer, so that the auxiliaries run with the set and independently of the main electrical system.

Fig. 23. The rotor of one of the Metropolitan-Vickers alternators being lowered into position

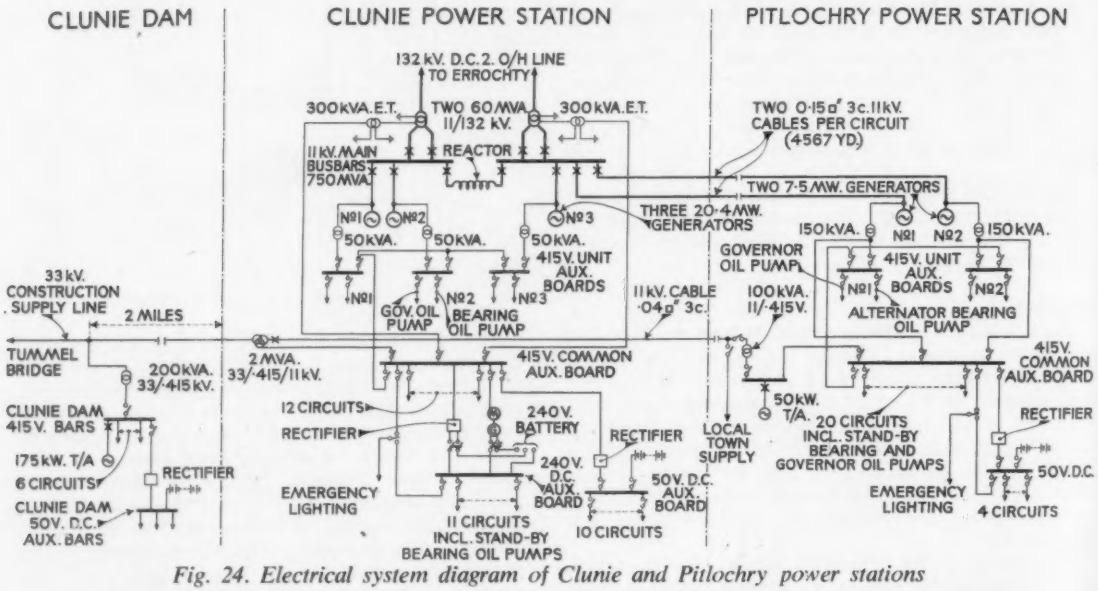


Fig. 24. Electrical system diagram of Clunie and Pitlochry power stations

Main Electrical System

As explained in our article on Clunie station, Pitlochry has no main switchgear but is treated electrically as an extension of Clunie. This will be clear from the system diagram reproduced in Fig. 24. Each machine at Pitlochry is connected solidly to a main circuit breaker at Clunie by two 0·15 sq. in. three-core cables in parallel, the distance being about 2½ miles. At Clunie the main switchgear is of the single-busbar oil-filled type and is in two sections coupled through an outdoor reactor rated at 5 per cent. on 20,000 kVA. Two of the Clunie sets, which are rated at 20,400 kW, feed one section, and the third Clunie set and the two Pitlochry sets feed the other. Each section supplies a 60 MVA transformer bank stepping up to 132 kV, the power being taken

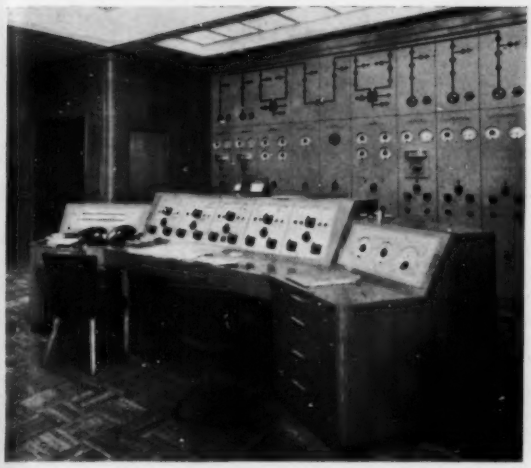


Fig. 25. The main control room at Clunie from which Pitlochry is supervised

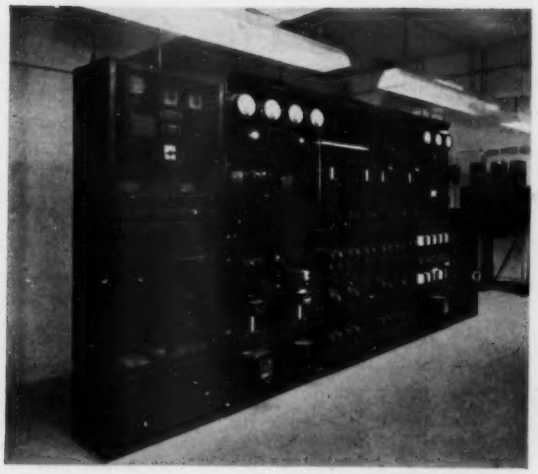


Fig. 26. Charging panel for the Ediswan 240 V and 50 V batteries at Clunie

by a double-circuit steel-cored-aluminium overhead transmission line to a new substation between Tummel Bridge and Errochty power stations. This substation will become the collecting point and control centre for the whole group of stations in this catchment area, and from it the power will be taken southwards to the British Electricity Authority's system at Bonnybridge and Abernethy.

In the control room at Clunie, depicted in Fig. 25, the principal controls on the main board are duplicated on a control desk from which all routine operations except synchronising can be carried out. Direct telephone communication to Pitlochry as well as other vital points of the system is available from this control desk. On the control alarm panel the operation of all fault, protective and warning devices at Pitlochry is displayed in detail, and the hydraulic panel includes indicating and recording instruments giving the reservoir level, river flow and other necessary quantities at Pitlochry dam. Except, therefore, for the actual operation of the turbines and hydraulic equipment, Pitlochry station is controlled entirely from Clunie.

Direct current for the control circuits is furnished by an Ediswan 240 V battery at Clunie, and a supply is taken by land line to Pitlochry. For telephones, instruments and alarms there is a 50 V Ediswan battery at Clunie and a similar one at Pitlochry.

Conclusion

In concluding our descripton of this stage of the Tummel-Garry scheme we have pleasure in acknowledging our indebtedness to Sir Edward MacColl, Deputy Chairman and Chief Executive Officer of the North of Scotland Hydro-Electric Board, for permission to visit Pitlochry and to publish this article. We have also received the utmost assistance from Sir Alexander Gibb and Partners and Messrs. Merz and McLellan, the consulting engineers for the civil and the mechanical and electrical work respectively.

The architectural consultants were Messrs. Tarbolton and Ochterlony, and the principal contractors were as follows:

Turbines designed by	Boving & Co. Ltd.
„ manufactured by	Glenfield & Kennedy, Ltd.
Governors	Steele & Cowlishaw, Ltd.
Water and oil pumps	Mirrlees, Bickerton & Day Ltd.
Compressors	Broom & Wade, Limited
Alternators and exciters	Metropolitan-Vickers Electrical Co., Ltd.
Turbine-house crane	Babcock & Wilcox Ltd.
Auxiliary switchgear	The British Thomson-Houston Co. Ltd.
Auxiliary transformers	Bonar Long & Co. Ltd.
11 kV cables	British Insulated Callender's Cables Ltd.
Lighting, heating and auxiliary cables	Matthew Hall & Co. Ltd.
Compensation water turbine	Gilbert Gilkes & Gordon Ltd.
„ „ alternator	Bruce Peebles & Co. Ltd.
Dam and power station building	G. Wimpey & Co. Ltd.
Drum gates	Glenfield & Kennedy Ltd.
Draw-off gates and turbine intake and outlet gates	Glenfield & Kennedy Ltd.

Metropolitan-Vickers Electrical Co. Ltd. announce that the third 18 MVA 75 r.p.m. vertical shaft generator for Tainionkoski, Finland, was erected early in the year, and the whole station has been brought into service. Two of the three 32 MVA 428 r.p.m. horizontal shaft generators for Cavado, Portugal, have been completed. (These form part of an extensive contract being executed jointly with the English Electric Company). Further vertical shaft generators now completed are the first of three 14,100 kVA 428 r.p.m. machines for Moyar in Madras and the second 8,333 kVA 167 r.p.m. machine for Kaplan turbine drive at Pitlochry in Scotland.

Among new orders for vertical shaft generators are three machines of 82·5 MVA 214 r.p.m. for Saltos del Sil, Spain, together with associated transformers and switchgear; these generators are a record size for British manufacturers. Four machines of 27,777 MVA 136 r.p.m. have been ordered for Whakamaru in New Zealand, and two of 17·1 MVA 650 r.p.m. for Kiewa, Victoria, for which four similar units were previously in hand.

The Owen Falls Scheme

A development of major importance to East Africa. In this article John Hartley discusses some of the technical problems involved.

AS a civil engineering project, the construction of the new hydro-electric power station at the Owen Falls, Uganda, has some interesting features. The site has a great deal in its favour, and although there is always the possibility of meeting difficult site conditions, no major ones have appeared so far.

Nearly two miles down the White Nile from Lake Victoria the main channel of the river is narrowed considerably by a spur of rock just below the Owen Falls. The width of the river here is about 500 ft., the bed consisting of extremely hard rock. From the lake to the Owen Falls, the river has cut a channel through the surrounding plain with occasional rock bars forming a series of minor falls. At the site of the work, the river has dropped 60 ft. in level below the lake, and this head in conjunction with a raising of the lake level is being developed for power by means of a dam with a power station alongside it.

Lake Victoria is the world's third largest lake, with an area of 26,000 sq. miles, and consequently has a very large storage capacity for a limited range of water levels. The total catchment area of the White Nile at its source at Ripon Falls is 103,000 sq. miles, of which the lake itself represents almost exactly a quarter. Apart from this unusual circumstance, another feature of the area is the heavy loss of rainfall in evaporation and transpiration.

Of the rain falling on the catchment, it is estimated that 7 per cent. only passes Ripon Falls, or if there were no losses the runoff would be 14 times as large as, in fact, it is. The discharge of the river has been reliably estimated from a series of lake level readings and river discharges covering a period of over fifty years. The mean discharge of the river is about 22,000 cusecs. The presence of the large lake damps out the fluctuations of the discharge, the known minimum being about 10,000 cusecs and the known maximum about 43,000 cusecs which is quite a small variation of flow. The lake is 3,716 ft. above sea level and its natural variation of level is quite small, between five and six ft. When the lake is dammed its deep water level will be 3,723·5 ft. and the normal range of operation 10 ft. At the outlet of Lake Victoria, about one and three-quarters of a mile above the Owen Falls, are the Ripon Falls. These falls will eventually be submerged and part of the rock formation removed to ensure adequate discharge from the lake. Before then, they will be used to facilitate the construction of the new dam and power station.

Since the natural storage is so vast, it is possible to erect a temporary control at Ripon Falls and eliminate the high flows which would otherwise govern the design of the temporary works. The width of the river at the Ripon Falls is about 900 ft. and the water passes over a line of four falls separated by small islands. About half the water passes over

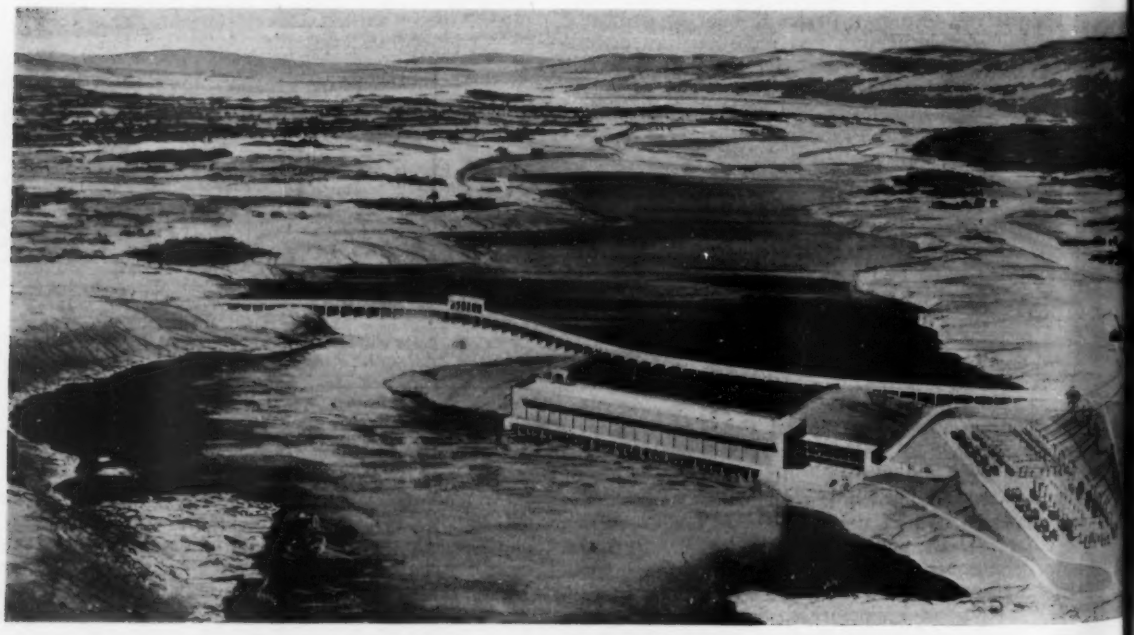


Fig. 1. Artist's impression of Owen Falls hydro-electric station and dam

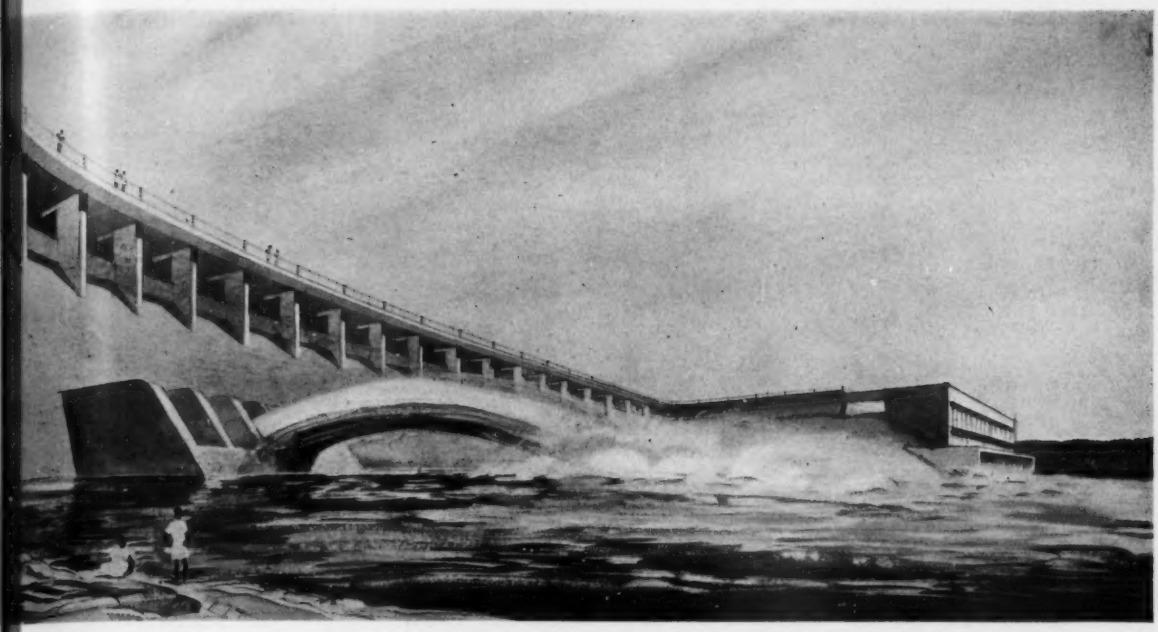


Fig. 2. Another aspect of the dam and power house

one particular fall on the west side of the river. This fall will be blocked off with a temporary dam and replaced by an artificial channel on the east side which will be controlled by means of stop logs. In this manner it is proposed to restrict the flow at the Owen Falls during constructional work to about 22,000 cusecs and the cofferdams are constructed to pass a maximum flow of about 28,000 cusecs without overtopping.

When he was in London recently Mr. C. R. Westlake, chairman of the Uganda Electricity Board, spoke with some confidence on the progress of the scheme. The proposal in the first instance was, he said, to put up a hydro-electric power station in the heart of Africa to develop the area. In late 1946, Sir John Hall the present Governor asked Mr. Westlake to report on the development of the Uganda resources. The report was as much an economic survey as an engineering report but was accepted immediately by all sections of the community.

Two firms of consulting engineers made a further report which was presented in July, 1948, and gave estimates of cost which have since been increased because of rising costs. By the end of 1948 contracts had been let for all the electrical and mechanical plant, and civil engineering contracts were settled by September, 1949. The cost of the civil engineering works at that time was about £3,500,000 but this had since gone up about 20—25 per cent. through increases in costs of labour and machinery. The same increases applied also to the electrical and mechanical plant. The board will ultimately be spending £15 million to £16 million on the scheme, including about £750,000 on housing and £2 million to £3 million on transmission of power over an area of about 1,000 square miles. The board is confident that the tariffs offered to industry will be competitive with tariffs in almost any part of the world and judged by United Kingdom standards, somewhat lower than in Britain.

Work was started on the dam early in 1950 and a

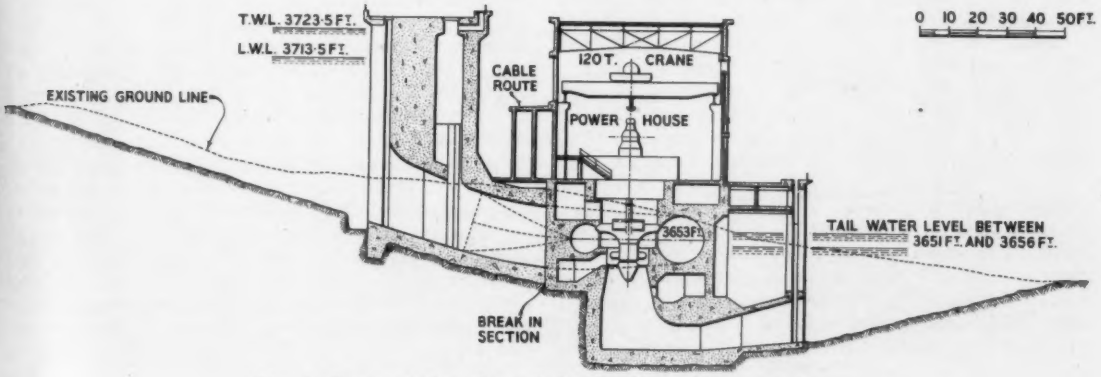


Fig. 3. Cross section through intake dam and power house

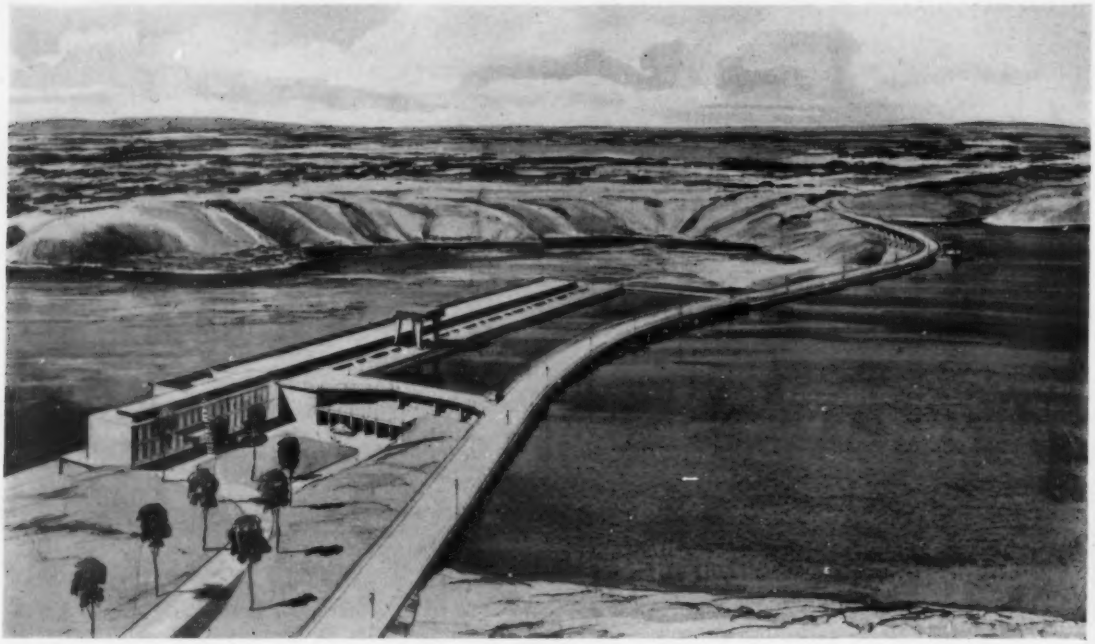


Fig. 4. Artist's impression of power house and roadway

modern camp including married quarters has been built for the African labour. This camp is claimed to be one of the best of its kind in East Africa. On the European site the houses have been built of permanent materials. There are about 2,000 Africans and 200 Europeans working on the site.

To provide power, two temporary thermal stations costing about £1 million are being installed. One has already been erected and the other is due for completion by the end of this year. By the time the first sets of the permanent station are operating it is estimated that the Diesel stations will be costing the board £1,500 a day for fuel.

On the main site the power house foundations have been cleared for the first two generator sets and the first permanent concrete was laid earlier this year. The first portion of the cofferdam required for the construction of the power station and the first cofferdam for the construction of the main dam, have also been pumped dry.

The rate at which plant will be installed in the power station will depend to some extent on the development of the mineral resources of Uganda—iron ore and phosphates in the east and the potentially great source of copper in the extreme west. When the first portion of the station is finished by about January 1954, installed capacity will be 60,000 kW but the station is intended for an ultimate capacity of 150,000 kW. The first unit is expected to be at work by March, 1953. Power has already been allocated for grain drying plant, a new factory and a cement plant which is being erected at the moment

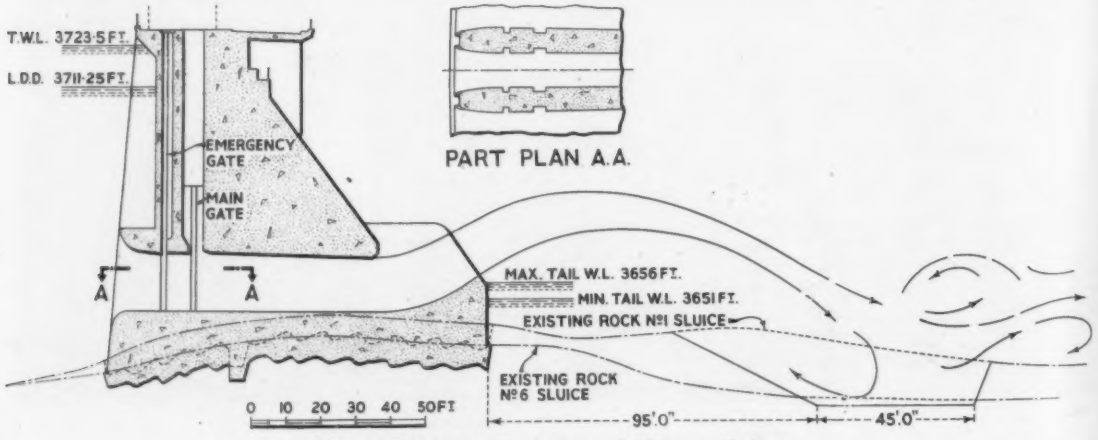


Fig. 5. Section through control sluice and dam

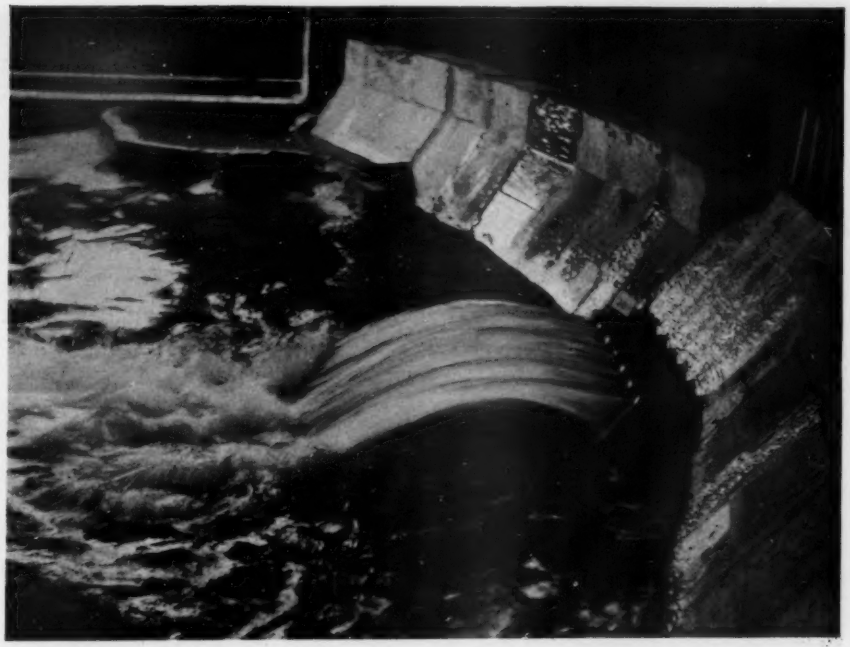


Fig. 6. A photograph of the model built at Imperial College, London, for design tests

and will be in operation before the end of this year.

It is hoped that this cement plant will make a substantial contribution to the cement requirements of the scheme, but at present all cement is exported from Great Britain. About 250,000 cubic yards of concrete will be required and the aggregate is obtained by crushing the rock excavated on the site.

After the first four 15,000 kW turbo-alternators have been installed, further units will be constructed according to the growing demand for power. It is for this reason and also the limitations of the railway from Mombasa that the size of the units has been restricted to 15,000 kW each. However, power development from the Nile in Uganda is by no means restricted to Owen Falls. The river has been examined and suitable sites for other power stations are possible within the next 60 miles downstream.

There is one function which the Owen Falls station will serve that has nothing to do with power. At the request of the Egyptian Government the dam is to be built one metre higher than is necessary for the requirements of power. In order to keep the Egyptian agricultural economy happy a tight control of the Nile is necessary to hold back vast quantities of water in wet years and release them in dry years. The Egyptian Government is to pay the board about £120,000 for the extra work to be carried out.

The new dam will affect the double-deck steel bridge which carries the road and the Kenya-Uganda railway over the Nile about three-quarters of a mile upstream from the Owen Falls. The lower deck containing the roadway will eventually be unusable at high reservoir levels, but the railway on the higher level will not be affected. The road is being diverted over the new dam, and across the power house forebay by a reinforced concrete bridge 650 ft. long. The road will be 22 ft. wide with a 6 ft. footway on one side.

The new station is being erected on the north side of the neck of the rock spur projecting from the west bank, and the neck will be excavated to form the forebay. The tip of the spur will be left in mid-channel to form what will virtually be an island. A gravity dam with deep sluices will be built across the main channel and from the island will return to the intake dam immediately upstream of the power house. The deep sluices to pass excess water in the early stages of power development, have been designed to accommodate high floods but will normally be operated to control the flow of the river in a manner which will be suitable for the requirements of Egypt. There are six sluices, each 16 ft. $8\frac{3}{4}$ in. high by 9 ft. $10\frac{1}{8}$ in. wide protected by an emergency gate for use as required for maintenance purposes. These gates will be controlled from a gantry at the top of the dam. The discharge culverts have buckets on their downstream ends to throw the water clear of the tow of the dam. The river will thus have two routes of discharge. First in its original bed through the flood gates and the second through the new cut on the west bank and through the power station. The capacity of the deep sluices alone is 45,000 cusecs compared with the known maximum flow of the level of 43,000 cusecs.

The total length of the main dam together with the dams on each side of the power station forebay and the intake dam at the power station will be 2,725 ft. (830·6 m.) with a maximum height of 85 ft. (25·9 m.). The width of the river at the dam will be about 1,300 ft.

The station is designed for an ultimate installed capacity of 150,000 kW made up of 10 alternators of 15,000 kW each driven by Kaplan turbines designed to operate under a head of water which may vary between $57\frac{1}{2}$ ft. and $72\frac{1}{2}$ ft. (17·5 m. and 22·1 m.), the maximum flow through each turbine being 3,600 cusecs (about 100m/sec.). This building will be about 585 ft. long (178 m.).

On both sides of the headrace of the power station

Fig. 7. Aerial view of the site showing the succession of falls

there will be subsidiary dams and there will be a third dam — the intake dam — upstream from the power station. This dam will be a gravity structure, the inlet of water to each of the turbines being controlled by a main gate in front of which will be screens which can be removed and replaced by a bulkhead gate when the main gate requires servicing. Tail water levels against which the turbines discharge will not vary more than five feet.

Before the ultimate designs were approved extensive experiments to calibrate the sluices were made with models at Imperial College, South Kensington, London, under the direction of Professor G. M. White, Ph.D., D.Sc. Because of the facilities available at Imperial College the contractors were also able to check the height of the cofferdams and the main levels for the various stages of cofferdam construction.

The first stage of construction on the site consisted of excavating on the right bank to maintain the flow of the river while the cofferdams for the main power station are built on the left bank. Part of the dam will be built in alternate 15 ft. sections which besides providing temporary openings for the river to pass through during the second stage, will allow for the contraction of the concrete on cooling. The third stage will consist in constructing the remaining dam sections in the gaps and adding the upward curves on the spillway sections which will have been left out previously in order to increase the discharge capacity while work is in progress.

The consulting engineers to the Uganda Electricity Board are Messrs. Kennedy & Donkin for the electrical and mechanical work and Sir Alexander Gibb & Partners for the civil engineering work.

The contract for the construction of the civil engineering and building works has been let to a group of firms comprising four British and four Dutch firms: Christiani & Neilsen Ltd., Messrs. Dorman Long & Co. Ltd., Messrs. J. L. Kier & Co. (London) Ltd., and Messrs. Edmund Nuttall Sons & Co. (London) Ltd., being the British members and Hollandsche Beton Maatschappij N.V. Naamlooze Vennootschap Internationale Gewapendbeton Bouw. N.V. Nederlandsche Anneming Mij., and N.V. Nederlandsche Beton Maatschappij Bato, the Dutch Members. The group is known as the Owen Falls Construction Company. The structural steel is being provided by Messrs. Redpath Brown & Co. Ltd., the water turbines by Messrs. Boving & Co. Ltd., the generators by the British Thomson-Houston Co. Ltd., the 33 kV switchgear by the General Electric Co. Ltd., and 33/66 kV transformers by Messrs. Bruce Peebles & Co. Ltd.

Acknowledgment is made to the chairman of the Uganda Electricity Board for permission to print this article and to Sir Alexander Gibb & Partners for assistance in the preparation of the subject matter.

Transmission Gearing. The Buffoline Noiseless Gear Co. Ltd. have sent us a copy of a liberally illustrated booklet containing details of their products. This firm manufactures spur, bevel and helical gears, in metal, rawhide, paper, fabric and composition, as well as shear gears, couplings, sprocket wheels and gear units.

Blaw Knox Limited. A series of catalogues issued by this firm refer to the Wellpoint system of predraining subsoils before excavation work begins, the "B.K. Fifty" ½ cu. yard capacity excavator, and hydraulic angledozers for "Caterpillar" D2, D4, D7 and D8 diesel crawler tractors. All three catalogues are fully illustrated and the explanatory text is strictly technically and succinctly written.

Tunnel Driving in the Highlands

Data are given in connection with tunnel drivages using tungsten-carbide detachable bits and light drills supported by a pneumatic leg in granite and other quartzose rocks.

REFERENCE has already been made in this journal to the construction of the main tunnel* which supplies the water from Loch Sloy to the new power station on the banks of Loch Lomond. In that article some account was given of the various aqueducts and subsidiary works that were being undertaken to extend the natural catchment area of the scheme and we are now able to give additional details of the tunnelling operations in the Butterbridge section. This work was begun in April, 1948, and the last tunnel was completed on June 1st, 1950. There are three tunnels having an aggregate length of nearly four miles and all were driven by Silver Dart Wet Handrils manufactured by Holman Bros. Ltd., in conjunction with this firm's Airlegs and detachable tungsten-carbide bits. We understand that this is the first major tunnelling operation that has been undertaken in this country in hard rock where such a combination has been used throughout, and we are indebted to the North of Scotland Hydro-Electric Board and Balfour, Beatty & Co. Ltd. for permission to collect and publish the following data.

The No. 7 Lower Tunnel has a section 6 ft. 6 in. square and is 8,313 ft. in length. Two faces were maintained and the average weekly rates of progress per face were 83 ft. and 73 ft., although on occasions these rates were greatly exceeded, the maximum being 163 ft. for one face and 273 ft. for both. Three eight-hour shifts were maintained with eight men per face.

This tunnel was driven through Maol Meadhonach with a maximum cover of about 1,000 ft., the rock encountered being mainly granite, with zones of gabbro, mica schist and hornfels—the last being metamorphosed slate altered by contact with the granitic intrusion. Normally a 20-hole round was used with a five-hole burn cut, the average advance per round being 6·47 ft. At first the labour force was quite unskilled and progress was slow; the improvement effected as the men became more proficient and were

* "Loch Sloy," Sept.-Oct. 1950, page 185.

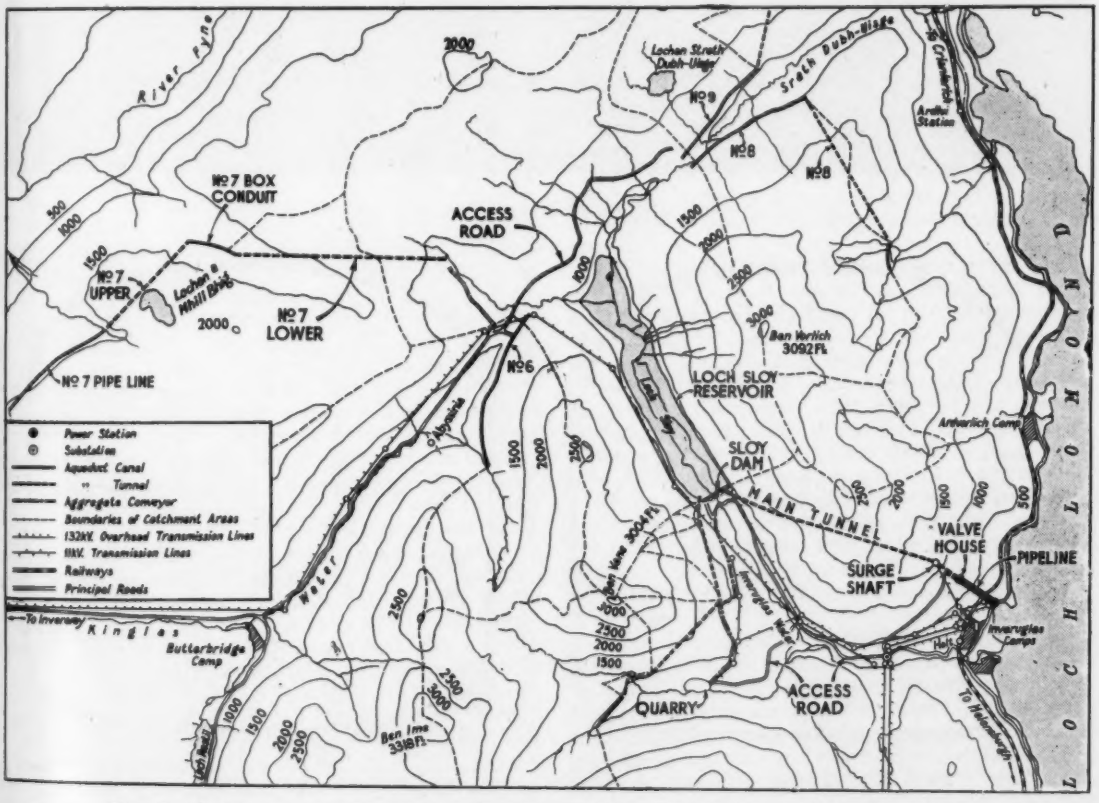


Fig. 1. Sketch map, not to scale, indicating position of tunnels mentioned in the text

Fig. 2. Drilling equipment in car, indicating compactness

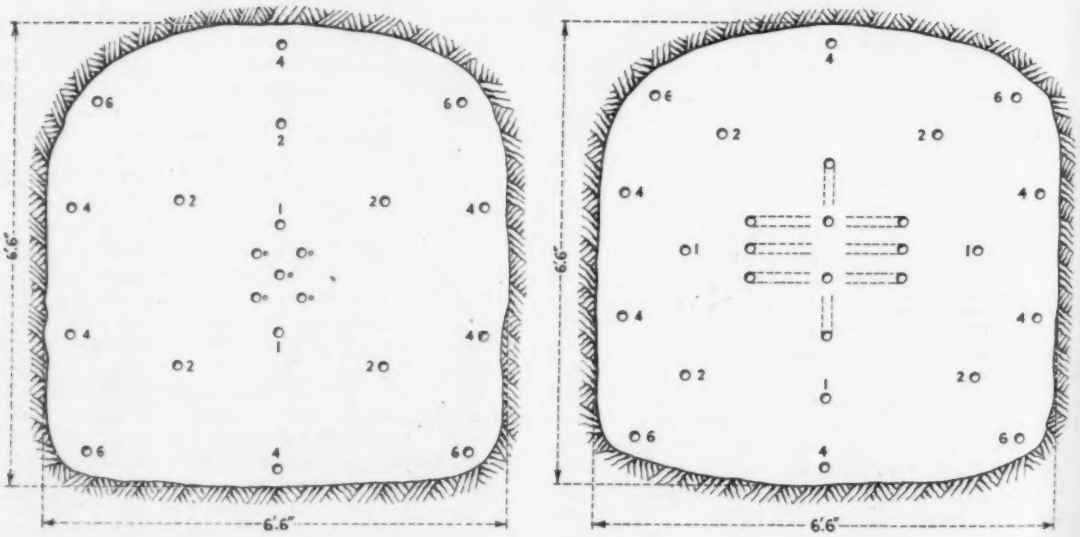


Fig. 3. Shothole patterns finally adopted (left) for softer ground and (right) for tough mica schist

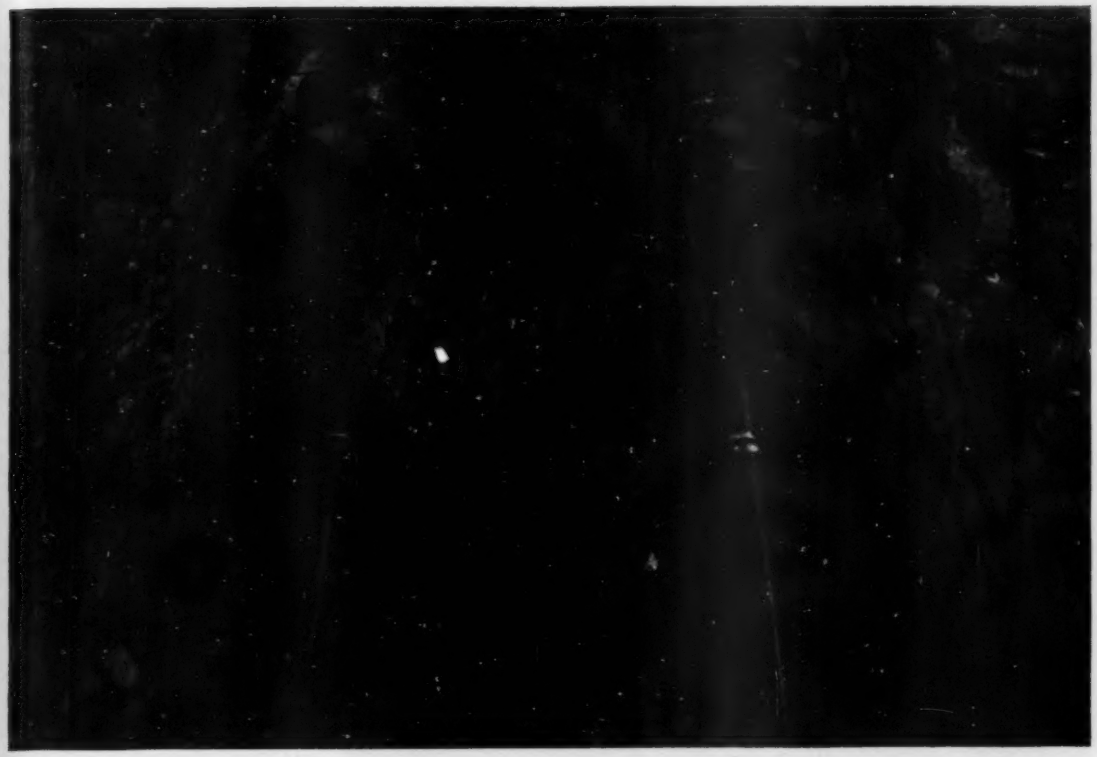


Fig. 4. Holman Handrils with Airleg attachments

joined by skilled personnel is interestingly reflected by the fact that from April to August, 1948, the average weekly rate of advance in the lower heading was 30 ft. whereas in the succeeding period, up to January, 1949, this rate had been increased to an average of 60 ft. per week. Subsequent to that date the rate went up to 112 ft. per week.

The total volume of rock removed was 15,900 cu. yards, requiring a total of 218,938 ft. of drill holes, 50 tons of explosive and 5,526 hours of drilling time. In spite of the tough siliceous rock the average depth accomplished per Holbit was 182 ft., the total number used being 1,205.

The No. 8 tunnel was driven from the Strath Dubh Uisge valley, through Stob an Aona Bhacain under a maximum cover of 700 ft. and for a total distance of 7,850 ft. All the drivage was from the outfall end, and at about 6,500 ft. from the portal a branch heading was driven 400 ft. to the left to connect with a 30 ft. shaft. Micaceous and quartzose schists were the predominant rocks encountered and as they were tough and heavily foliated great difficulty was experienced in pulling the rounds to depth. Many different patterns were tested, those indicated in Fig. 3 being finally adopted. With the 8—10 hole pyramid cut, seven easers were drilled and 10 ring holes. An average of 5·49 ft. was made per round and the average weekly rate of progress was 83·5 ft. with 150 ft. as a maximum. As in the No. 7 Lower Tunnel, no skilled labour was available and progress was slow until the men became experienced.

The No. 8 tunnel constitutes the longest drivage from a single heading in the Loch Sloy Scheme and involved the excavation of 15,671 cu. yards of rock, in which 122,721 lb. of explosives were used. Some 227,700 ft. of holes were bored in 5,913 hours of drilling time. The number of Holbits consumed was 1,001. The average footage drilled per Holbit was 227·5, which can be regarded as an exceptionally good performance considering the tough, uneven nature of the ground.

The remaining tunnel of the Butterbridge section is the No. 7 upper drivage which connects the Gleann a' Mhill Bhig to Eas Riachain through the shoulder of Meall Beag, a distance of 4,150 ft. Here the rocks consist of schistose grits with a porphyritic sill and subordinate bands of micaceous schists. It pulled much more consistently than either of the previous tunnels, as is reflected in the fact that the average advance per round was 7·41 ft., bringing the average rate of progress per working week up to 132 ft., with 234 ft. as an exceptional maximum. Rather more than 7,900 cu. yards of rock were removed, involving 111,272 ft. of drill holes and the consumption of 548 Holbits. The length of holing drilled per bit works out at 204 ft. Nearly 1,600 drilling hours were occupied in this work.

In considering these results it is manifest that no two rocks have precisely the same characteristics and, of course, this invalidates exact comparisons. But our data suggest that the tungsten-carbide bit has made out a clear case for itself by its performance on tough irregular quartzose rocks which offer as difficult a proposition as drilling equipment is likely to encounter.

C.P. "Feedleg" Rock Drill

With the vast amount of tunnel driving in hard rock which is now being carried out all over the world, a great deal of experience has been gained on the relative merits of different drilling techniques. One

of the most interesting developments arising from this experience is the use of light rock drills equipped with a pneumatic leg as a support feed. This drilling method is continental in origin, and is by no means new, but it has never really received the serious attention of tunnel contractors until comparatively recently, possibly because its success has been closely tied up with the introduction of the tungsten carbide drilling bit. It was found that while this type of bit provided the hardness and long life needed for even the hardest of rock, its use with the heavy drifter type machines was restricted because the heavy blows of these machines tended to fracture the tipping. To secure the advantages of the bits, therefore, it was necessary to employ lighter types of rock drills, and hand-held machines were brought into use. The logical development from this, of course, is the employment of a pneumatic support leg, and thus we now have a very effective combination—a light rock drill, a support leg, and a tungsten carbide tipped drill.

The merits of this new set-up in certain conditions are obvious and have been demonstrated in actual practice. One of the big advantages, of course, is the cutting of time losses in setting up and dismantling heavy equipment. Secondly, it provides complete freedom of action for taking up drilling positions which the rigid types of mounting made rather restricted and cumbrous. Thirdly, the initial cost of equipment is considerably reduced and the maintenance is low.

A newcomer into this field is the "Feedleg," which has just been introduced by the Consolidated Pneumatic Tool Co. Ltd. Among the advantages claimed for this design is the increased size of the piston rod, which is stated to have overcome all tendency to "whip" and to prevent breakage at the point where the piston is attached to the drill bracket. The increased piston size is also claimed to impart considerably greater rigidity at all drilling positions. Another feature is the simplified twist-grip throttle which has only one moving part, a point of some importance from the maintenance angle and which affords an exceptionally fine control. It is double acting, and the slightest twist produces an instantaneous response in the extension or retraction of the piston rod. Indeed, the graduation in control is infinitely variable from zero to supply line pressure.

A further point of interest is the mounting bracket whose function it is to counteract the reactionary force set up by the hammer blows of the drill. The aim of this design has been to maintain true alignment of the drill and drill rod and so eliminate excessive chuck wear.

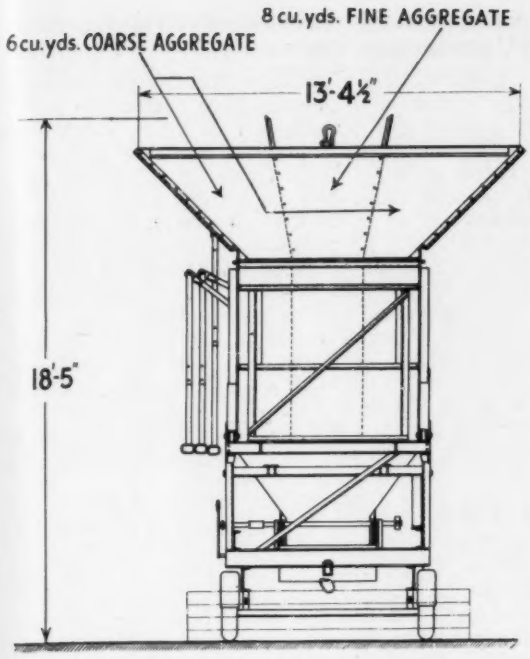
Other refinements include a "tell-tale" port in the cylinder to give the operator positive indication that the piston rod has reached the end of its travel; a wide sprag to improve stability and provide a good check for the backward thrust at all drilling angles; a bayonet fitting for speedy mounting of the drill, and a hardened steel sleeve which can be replaced instead of replacing the whole piston when wear takes place in the male end of the bayonet fitting.

The Feedleg has a 4-ft. stroke, weighs 47 lb. and has an overall length varying from 5ft. 10in. closed to 10ft. 1in. extended. It is employed with the C.P.-32 light rock drill, and in combination with this firm's tungsten carbide tipped drill stem.

"Junior Weighbatcher"

The accompanying illustrations show a modification of the Blaw Knox Junior Weighbatcher which is now available as a three-compartment machine with an increase in storage capacity amounting to 50 per cent. This achievement has been accomplished without in any way restricting the mobility as compared with the two-compartment equipment, and the pneumatic tyred wheels and over run brake comply in all respects with the Road Traffic Act.

The capacity is 40 cu. yards per hour, that is, sufficient to maintain two 14 S. mixers with accurately proportioned aggregates. Operation is within the compass of one unskilled man whether feeding to the concrete mixers singly or in pairs, so that the crews normally used to load the mixer skips can be released for other duties. The weigh hopper has a capacity of 26 cu. ft., the balancing mechanism resting on knife edges and not depending on springs. All the operating



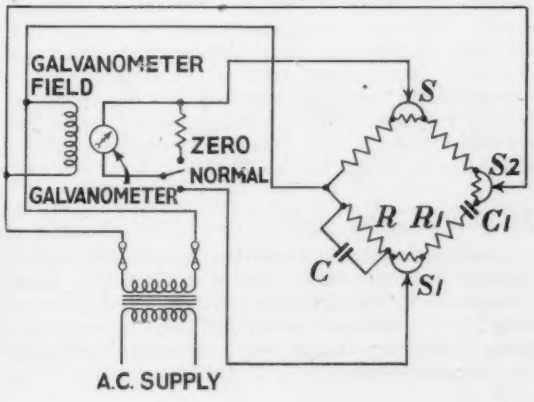
levers are grouped on one side of the machine and within immediate view of the weigh dial. Both the levers and the weigh dial can be transferred to either side of the machine, this feature being of great convenience when two weighbatches are worked side by side with the cement stock pile arranged between them. The counter-balanced sub-chute is so designed that it will swing up into a vertical position, thus enabling the batches to be used with any elevating hopper mixer. Telescopic front legs are fitted which facilitate the unit to be levelled on timbers or other convenient supports. The whole equipment can easily be towed by a light lorry; the flare plates and certain other components being dismantled and carried in the body of the lorry.

New Frequency Recorder

The accurate recording of the frequency of electrical power supplies is of importance in a number of industries, notably of course in the electricity supply industry itself. There has for some time been a need for a recorder of extremely high accuracy covering the small range of frequency usual for power supplies from the grid or from industrial power plant. This demand is now met by George Kent Ltd., who have developed a reliable instrument from a prototype originally designed for use in the firm's own research department.

The circuit of the instrument is shown in Fig. 1. Basically, it is a Wien bridge. The resistances and condensers, R, R1, C, C1, have the values necessary to provide the required range of the instrument, usually 47 to 51 cycles per second. S, S1 are mechanically coupled slidewire contacts working in tandem which balance the circuit until no current is passing through the galvanometer, according to the well known null-point method of measurement. The scale of the instrument is approximately linear. Accuracy is of a high order: $\pm$ 0·03 cycles per second over the whole range; while the recorder is sensitive to changes in frequency of less than 0·01 cycles per second. While the range 47 to 51 cycles per second is normal with this new instrument, the circuit values can be adjusted to cover other small ranges of frequency.

Many applications for this instrument suggest themselves. In Commonwealth countries such as Australia the reorganisation of electricity supply makes desirable the continuous recording of frequency values at power stations, etc. At home also, in these times of power shortage, it is of importance to power plant engineers to be able to demonstrate the performance of their stations, particularly during overload periods, by means of load charts and a frequency record. Of course, by modifying the scale to read revolutions per minute, the instrument may be adapted to record the speed of operation of a generator, where speed variations cover a short range only. Standard scales at present available read 47 to 51, or 48 to 52 cycles per second.



Digest of this Issue

Sommaire

Mise en valeur de la Volta (page 204).

Détails préliminaires de ce projet, étudié sous les auspices du gouvernement de la Gold Coast, qui envisage l'exploitation de l'énergie hydro-électrique à Agena, sur la Basse Volta, et à Bui, sur la Volta Noire; il comporte aussi des plans d'irrigation, d'assèchement et d'aménagement du transport fluvial.

L'industrie Hydro-électrique en France. 1ère partie. Par Pierre Chevrier et Stéphane Ferry (page 205).

Cette étude très complète retrace l'évolution de l'industrie hydro-électrique en France depuis son commencement, en 1890, et définit les grandes lignes de son expansion probable. L'accroissement constant de la puissance des génératrices et de l'envergure des projets, aujourd'hui conçus à l'échelle nationale, est caractéristique. La liaison des différents ensembles vise à obtenir, autant qu'il est possible, la régularisation saisonnière; à cette fin, le réseau de transport (150 et 220 kV) a été étendu de 9 000 kms. en 1938 à 14 000 kms. aujourd'hui. Il atteindra dans cinq ans 18 000 kms., avec certaines lignes à 380 kV. Les auteurs soulignent qu'une évaluation correcte des ressources potentielles de houille blanche en France demande une étude détaillée de tous les cours d'eau; cela n'a pas encore été fait. Ils estiment que la capacité totale des installations en service en 1954, lorsque le programme en cours aura été éxécuté, ne dépassera pas le tiers des ressources disponibles. Comme il est probable que toutes les ressources seront exploitées dans l'espace d'une génération, il importe de ne pas sacrifier celles dont la valeur présente est douteuse mais qui peuvent s'avérer précieuses dans un avenir proche.

Un voyage d'étude dans les Alpes. 2eme partie. Par le Dr. Charles Jaeger (page 213).

L'auteur, éminent ingénieur conseil, décrit certains des aspects qui ont retenu son attention au cours d'une visite récente des stations génératrices souterraines dans les Alpes françaises et italiennes. Il mentionne en particulier le barrage de Tignes et les stations de Malgovert et des Brévières — matériel installé, difficultés rencontrées dans la construction du tunnel de pression, béton employé pour le barrage. Il expose de même en détail les caractéristiques du barrage de Sta. Gustina, dont la partie supérieure est formée de voûtes encastrées independantes tandis que les voûtes épaisses de la base ont été calculées suivant la théorie des cylindres épais.

Pitlochry. 2eme partie (page 219).

L'auteur décrit ici en détails la station génératrice, équipée de deux groupes Kaplan de 7 500 kW. Cette installation s'inscrit, au point de vue électrique, dans le cadre de la station de 60 000 kW de Clunie, à deux miles environ en amont. Le système de distribution est brièvement décrit.

Aménagement Hydro-électrique dans l'Uganda (page 226).

Le lac Victoria, le troisième du monde par l'étendue, sera le réservoir d'emmagasinage colossal du projet hydro-électrique actuellement en cours d'éxécution en Uganda, et qui utilisera la puissance des chutes d'Owen, sur le Nil Blanc. La station génératrice, dont la capacité totale sera de 150 000 kW — avec 10 alternateurs de 15 000 kW—doit entrer en service en Janvier 1954. La première des quatre génératrices débitera en Mars 1953. Ces installations ont pour but la mise en valeur des ressources minières de l'Uganda —fer, phophates et cuivre en particulier.

Le site, à 2 miles en aval du Lac Victoria, apparait très favorable. Le fleuve coule dans un chenal aux rives fermes; la variation annuelle normale de niveau du lac est à peine de 5 à 6 pieds; et le débit du fleuve ne varie que de 1 à 4 environ—10 000 cusecs est le minimum connu et 43 000 cusecs le maximum. Le soubassement rocheux est très dur.

Deux faits remarquables méritent d'être notés: avec 26 000 miles carrés de surface, le lac occupe le quart de la zone de captage—103 000 miles carrés environ. D'autre part 93% des chutes de pluie sont perdus. Le barrage, d'une longueur totale de 830,6 m, sera surélevé d'un mètre afin de contribuer aux plans d'irrigation du gouvernement égyptien. Messrs. Kennedy & Donkin, pour les constructions mécaniques et électriques, et Sir Alexander Gibb & Partners, pour les travaux de génie civil, sont les ingénieurs conseils de l'Uganda Electricity Board.

Percement de tunnel dans les Highlands. (page 227).

Cet article rend compte des méthodes employées et des résultats obtenus dans le percement de plusieurs des longs tunnels que l'aménagement hydro-électrique de l'Ecosse a comporté dans les Highlands. L'emploi de l'équipement Hopman et de forets amovibles au tungstène a permis d'obtenir des rendements remarquables. Les équipes s'adaptèrent très vite à ce matériel nouveau; le chemin parcouru atteignit en certains cas 50 mètres par semaine sur une seule face. L'auteur précise la nature des roches rencontrées et la consommation de forets amovibles par rapport à la longueur et à la taille des tunnels percés.

Compendio de esta Edición

Proyecto del Río Volta (página 212).

Se facilitan detalles preliminares de este proyecto de la Costa de Oro, el cual está siendo apoyado por el Gobierno y que considera el desarrollo de potencia hidroeléctrica en Agena en la región baja del Río Volta y en Bui en la región Negra del Volta, junto con proyectos auxiliares y derivados para el riego y drenado de tierras, y para transporte fluvial.

La Industria Hidroeléctrica Francesa. Parte I. Por Pierre Chevrier y Stéphane Ferry. (página 214).

Se reproduce una descripción muy comprensiva de la evolución de la industria hidroeléctrica de Francia, desde sus principios en 1890 hasta el presente, con una relación de su probable expansión. Se pone de

manifiesto que su desarrollo ha sido caracterizado por un aumento constantemente creciente de los grupos de potencia y de la escala en que los proyectos han sido iniciados hasta que, en la época actual, la totalidad del planteamiento es realizado sobre una base nacional. En la actualidad los grandes proyectos son integrados para lograr en la medida máxima posible una regulación de temporada y con este objeto en vista las redes de transmisión (150 y 220 kV) han sido extendidas desde 9.000 kilómetros en 1938 a 14.000 kilómetros en los tiempos presentes. Durante los próximos cinco años esta red será extendida hasta alcanzar 18.000 kilómetros y las líneas funcionarán a 380 kV. Los autores hacen resaltar que el cálculo correcto de las reservas potenciales de energía hidráulica en Francia exigen un estudio muy detallado, el cual todavía no ha abarcado todos los ríos y arroyos. Ellos calculan que en 1954, en cuya época el programa actual tiene que ser completado, la capacidad total de las instalaciones hidroeléctricas en servicio no excederá una tercera parte de los recursos disponibles. Puesto que existe la posibilidad de que los recursos totales sean aprovechados dentro de una generación, debe desplegarse un mayor cuidado para no sacrificar aquellos recursos de un valor actual dudoso que en el porvenir podrían ser de muy gran valor.

Una Visita de Estudio en los Alpes. Parte II. Por Dr. Charles Jaeger (página 213).

El autor de este artículo, un eminente ingeniero consultante, describe algunas de las características que llamaron su atención durante una reciente inspección de centrales hidro-eléctricas subterráneas en los Alpes franceses e italianos. Se hace referencia a la presa de Tignes y a las centrales generadoras de fuerza motriz de Les Brevieres y Malgovert, facilitándose detalles de los equipos instalados, dificultades que tuvieron que vencerse en la construcción del túnel de presión y del hormigón empleado para la presa. Se facilitan detalles parecidos relacionados con la presa de Sta. Guistina, la cual es considerada como siendo formada por arcos elásticos independientes de construcción empotrada en la porción superior, mientras que los arcos gruesos para la porción inferior fueron calculados de acuerdo con la teoría de cilindros gruesos.

Pitlochry. Parte II (página 200).

Continuando nuestra relación de este desarrollo, se facilita una descripción de la central generadora de fuerza motriz. La instalación generadora comprende dos grupos Kaplan de 7.500 kV, los cuales son descritos detalladamente. La central funciona eléctricamente como parte de la central Clunie de 60.000 kV, a eso de unos tres kilómetros aguas arriba, y se facilitan breves detalles del sistema eléctrico.

Resumen del Proyecto Hidroeléctrico de Uganda.

Un proyecto hidroeléctrico que está siendo puesto a la práctica en Uganda utilizará el lago Victoria—el tercer lago del mundo en orden de importancia—como un enorme pantano de almacenaje y el manantial del Nilo Blanco en las Cataratas Owen para la generación de fuerza motriz. Se espera que en el mes de Enero de 1954 se dispondrá de una central generadora de fuerza motriz con una capacidad instalada final de 150.000 KW., consistiendo de diez alternadores de 15.000 KW. cada uno. Se calcula que en Marzo de 1953 ya estarán funcionando los primeros cuatro generadores. El objeto perseguido es el ayudar el desarrollo de los recursos naturales de Uganda, especialmente mineral de hierro, fosfatos y cobre.

El sitio de la obra en las Cataratas Owen, a tres kilómetros aguas abajo del Nilo desde el Lago Victoria, parece ser muy favorecido. Las aguas del río circulan en un canal con costados firmes. La variación natural del Lago es solamente de 1,52 a 1,83 metros aproximadamente, y la variación del caudal del río es solamente de uno a cuatro aproximadamente — el mínimo conocido es 283 metros cúbicos por segundo, mientras que el máximo conocido es de 1218 metros cúbicos por segundo. La roca sobre la cual se construirá la presa es muy dura.

Dos características poco corrientes son que la superficie del Lago—67.340 kilómetros cuadrados—representa una cuarta parte del total de la cuenca de vertiente de 267.000 kilómetros cuadrados aproximadamente; las pérdidas de lluvia de la cuenca ascienden a un 93 por ciento. Con miras a ayudar al Gobierno Egipcio en su economía agrícola, la presa tendrá una longitud total de 830,60 metros y será construída de una altura de un metro mayor de lo necesario para la obtención de fuerza motriz. Los Ingenieros Consultantes de la Junta de Electricidad de Uganda son los Sres. Kennedy & Donkin para los trabajos eléctricos y mecánicos, y Sir Alexander Gibb & Partners para las obras de ingeniería civil.

Perforación de Túneles en las Tierras Altas de Escocia (página 227).

Se facilitan descripciones de los métodos empleados y de los resultados obtenidos en la perforación de los extensos túneles que se están perforando en las Tierras Altas de Escocia para proyectos de energía hidráulica. Se han logrado cifras muy notables de avance de perforación con la adopción de equipos Holman, conjuntamente con el empleo de mechas retirables de carburo de tungsteno. Al principio el personal estaba muy poco entrenado, pero muy rápidamente se ha logrado introducir eficiencia en su trabajo y se han logrado avances de perforación hasta 50 metros por semana en una sola cara de perforación. Se indican detalles de la clase de roca que tiene que perforarse y del consumo de mechas desmontables con relación a la perforación y dimensiones de los túneles perforados.

Cavitation Research. A twenty-page bulletin, No. 02B7581, which describes interesting cavitation-pitting tests has been issued by Allis-Chalmers Manufacturing Company, of Milwaukee. These tests were conducted to solve some of the phenomena of cavitation and to determine the relative resistance to pitting of recently developed materials, and of the techniques for applying these materials. The text is based upon a paper presented at the annual meeting of the American Society of Mechanical Engineers by William J. Rheingans, assistant manager of Allis-Chalmers hydraulic department, and subsequently published in the ASME Transactions last year.

From the Journals of the technical institutions and other material published in the Press of the World

Draining seepage in dams

REPORTS on failures of dams always emphasise the decisive influence of seepage on the stability of these structures. Stability can be increased either by heavy rockfill protection on both sides of the dam, or by filtering layers inside the body of the dam, with an impervious core in the middle or an impervious blanket on the upstream slope. Various systems of filtering layers have been suggested; for instance, Reinius advocated filters built in on the upstream side of the dam as well, and obtained the pattern shown in Fig. 1, which ensures a temporary increase of stability when the water level of the reservoir is lowered rapidly. This means that, with an adequate system of built-in filters, the dimensions of a dam can be kept within narrower limits.

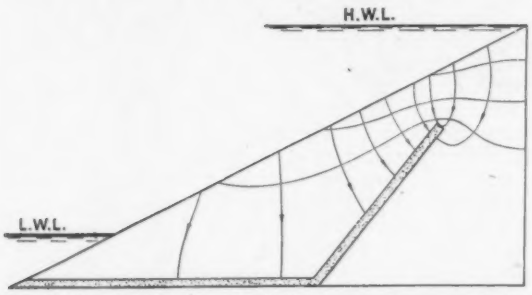


Fig. 1. Increasing dam stability on upstream side by means of an oblique filtering layer, and diverting the flow of seepage into the body of the dam

These filters consist of layers of graded material (river sand, gravel or sound crushed rock) which increase in fineness towards the outer face of the dam. The grain size of this material should be so determined as to prevent the seeping water from carrying the finer material into the coarser layers.

In a dam 165 ft. high and 1,650 ft. long at the crest, the drainage layer placed under the downstream half of the dam on top of the foundation will require as much as 100,000 tons of sand, gravel and crushed rock, and it is important that filtering material should be used as sparingly as possible. In a particularly difficult instance the author endeavoured to find solutions in which an adequate effect on seepage and stability could be attained with a minimum amount of filtering material. With the help of models he investigated how far surface filters could be replaced by separate layers, and at which intervals these layers should be located in order to have the necessary effect.

Proceeding from the fact that electric current in a conductor and water in a conduit, follow the direction of the greatest pressure drop, the author investigated the percolation of seeping water in the body of a dam by means of a two-dimensional electro-dynamic analogy in which the section of the dam affected by seepage is reproduced geometrically by an electric conductor (electrolyte), the voltage drop in the conductor being measured under strict observance of the given marginal conditions.

As it is impossible to reproduce in the electric analogy the effect of gravity on the flow of seeping water, the seepage line was determined by rule of thumb, proceeding from the condition that the no-pressure surface of the seeping water (seepage line) is cut perpendicularly by the equipotential lines at regular height intervals. If, therefore, the upper boundary of the seepage area is modified successively by altering the shape of the plastic insulator until the above condition is reached, the current will travel in the model in the same way as seepage in the body of the dam. The linear voltage drop along the upper boundary (seepage line) was obtained by means of an electric resistance consisting of a thin copper wire

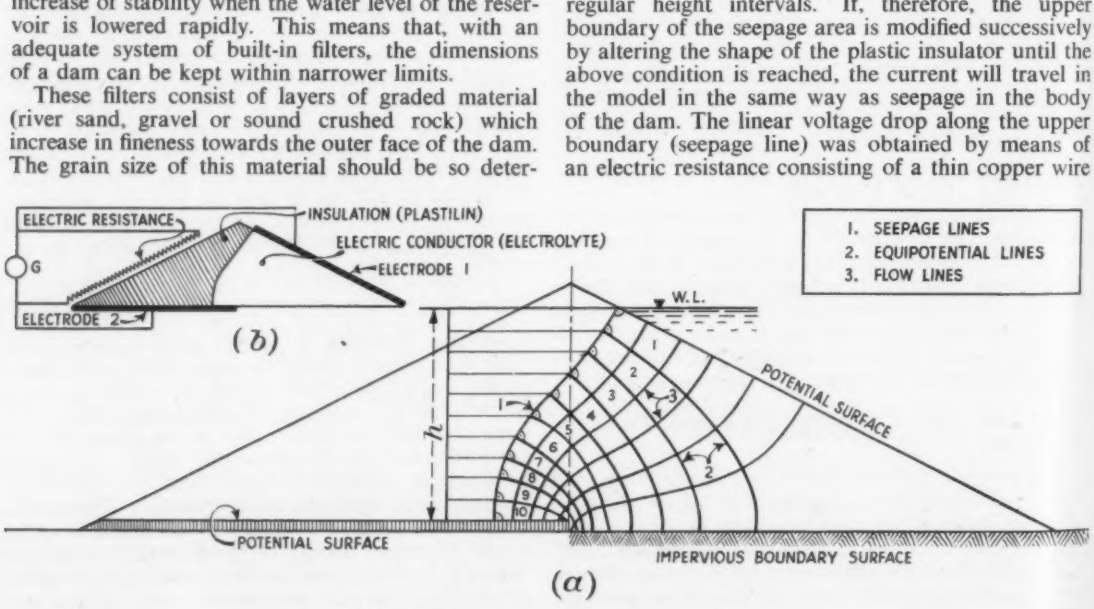


Fig. 2. Hydro-electrodynamic Analogy

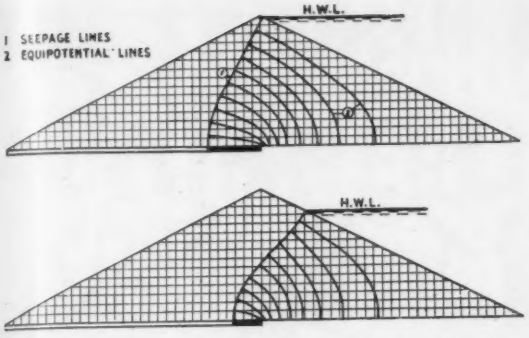


Fig. 3. Course of seepage line, and useful width, in relation to range of drainage inside the dam

coiled around a small "Pertinax" rod.

These tests confirmed the effect, on the flow of seeping water, of a horizontal filter layer placed at the base of the dam under its downstream half, as previously ascertained by de Vos, and demonstrated that:—

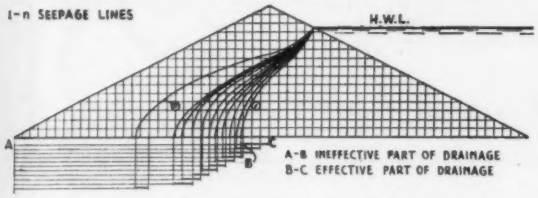


Fig. 4. Showing seepage lines and effective and ineffective part of drainage

(1) The seepage line is the steeper as the drainage layer penetrates farther inside the dam; (2) The useful width changes in accordance with the range of drainage inside the dam; and decreases with the water level in the reservoir; (3) A drainage layer sited in the middle of the dam must have, at a given water level, a determined minimum width so as to prevent the seepage line from reaching the downstream slope; (4) A small number of independent pipe drains, conveniently placed, will bring about the same diversion of the seepage line as a surface filter; (5) The inclined filtering layers often used in American dams have no greater efficiency than horizontal drainage, and rather hamper the dumping of material; (6) The inclination of the upstream face of the dam has but an insignificant effect on the course of the seepage line.

In his conclusion the author emphasises the advantage of independent pipe drains, laid at the base of the dam, over a rock toe on the downstream side. Their effect on the flow of seeping water and the diversion of the seepage line inside the dam, as well as the stress relief in the downstream half of the dam, are the same as with surface drainage. This, however, applies most particularly to dams built of dumped sand or gravel, in which the flow of seepage is determined exclusively by gravity, and not to clay or silt dams in which it has not yet been possible to determine the exact effect of drainage owing to the capillary attraction occurring in this kind of structure.—Dr. Herberth Breth, *Die Wasserwirtschaft*, Vol. 41, No. 4, January 1951, p. 89, 5 pp., 20 ff.

Developments in Siberia

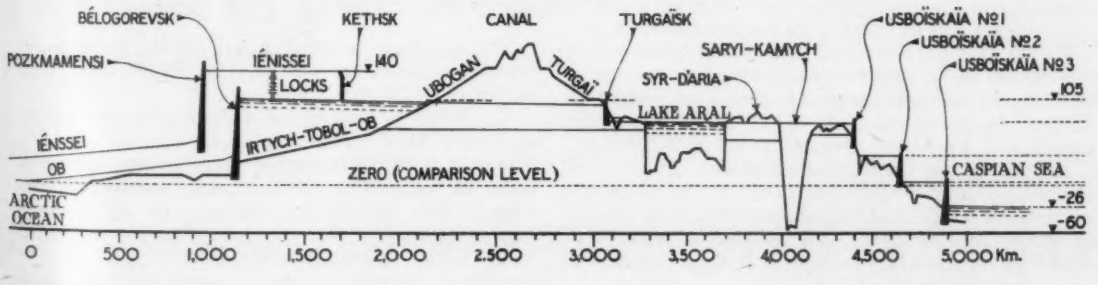
THE West Siberian Plain presents sharp contrasts: its boundaries in the West are the Ural Mountains, and in the East, the hills and plateaux of the Krasnoyarsk region (Sayan Mountains), while in the South the Kirgiz Steppe (Kazakstan) is bordered by the foothills of the Ural and Pamirs. This vast stretch of land is limited in the south-west by the Caspian Sea.

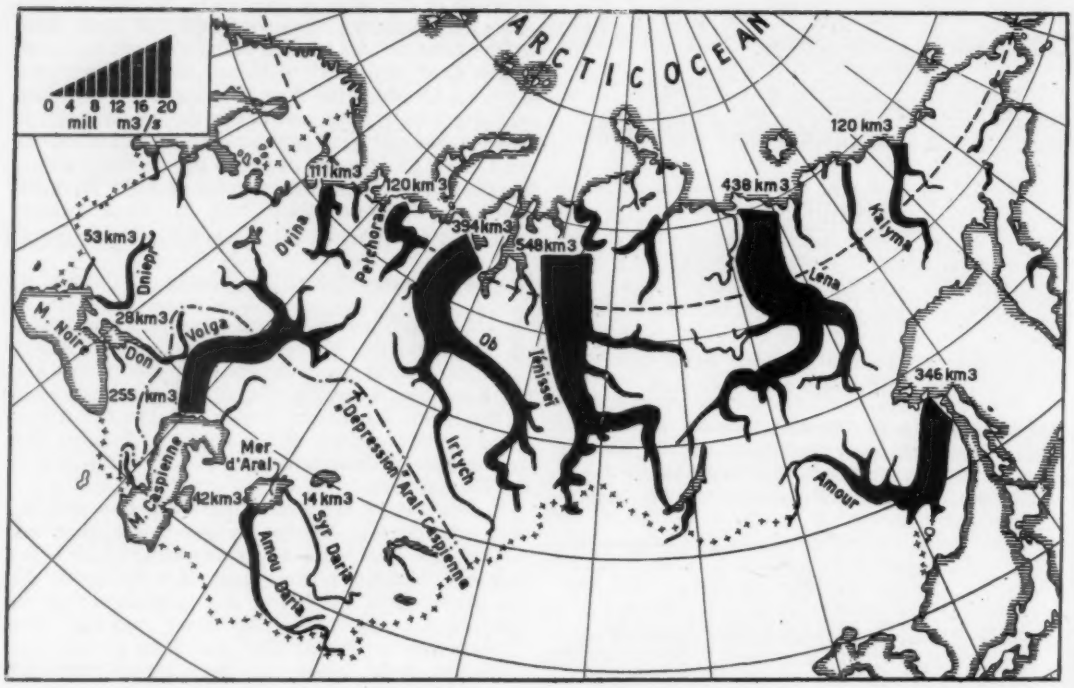
In recent years the level of the Caspian waters has been considerably affected by the Volga dams and will fall still more when the development of the Volga and its tributaries is concluded. It is estimated that the discharge of the Volga and tributaries into the Caspian Sea will have then been reduced from 255,000 Mm^3 to 75,000 Mm^3 p.a. Such an enormous reduction of the inflow into the Caspian Sea might have serious climatical repercussions.

What the Soviet hydraulicians have now in mind is no less than to re-establish, hydrographically speaking, the conditions which existed in the West Siberian Plain at the Ice Age or, in other words, to divert the surplus waters of the Siberian Plain through the Turgai Gate to the Caspian Sea. This gigantic artificial adduction will, at the same time, open the road to the agricultural development of the desertic Kazakstan regions.

The hydrographic conditions obtaining in U.S.S.R. are shown in the appended schematic map which demonstrates the prominent importance of such mighty streams as the Volga, Ob(Yenissei and Lena, as well as of the rivers of Kazakstan and those of the Aral, Amu-Daria and Syr-Daria basins. The aggregate discharge of all these rivers into Lake Aral amounts to 56,000 Mm^3, which will be used for the irrigation of 80,000 km^2 of land, thus reducing the area of this lake to 12,300 km^2.

The solution of the problem will require an additional supply of 180,000 + 56,000 = 236,000 Mm^3 of water to the Caspian and Aral region. Adding to this figure the irrigation requirements of the Turan districts (250,000 km^2), the total yearly volume of water necessary would be 300,000 Mm^3, that is to say an adduction flow of 10,000 m^3 per second.





The projects connected with this huge programme of development must have been worked out by the Soviet hydraulic engineer Davydov, and comprise the following works stages:—

At Bielogorevsk, at a certain distance from the confluence of the Irtish and Ob, a dam, 78 m. in height, will create a storage reservoir of 4,500 Mm^3 useful capacity, covering an area of no less than 250,000 km^2, and feeding a 5·6 MkW hydro-plant to generate 34,000 MkWh p.a. This storage reservoir will stretch, on one side, to Novosibirsk and Ketsk, and on the other, to Tobolsk, that is to say to about the line dividing the West Siberian and Aral-Caspian basins. Beyond this line, a canal 900 km. in length, averaging 40 m. in depth (maximum 75 m.), will be dug along the old beds of the Ob and Yenissei to bring the waters of the Ob and Irtish to the southern slopes of the Turgai hills, whence they will flow towards the vast Kazakstan plains and, finally, to the Aral lake whose level is 60 m. above sea-level.

The distance between the Bielogorevsk Dam and the Caspian Sea is of the order of about 4,000 km., the waters running about 1,800 km. through seas, lakes and storage reservoirs, 950 km. in the beds of old rivers, and 1,200 km. in new canals.

Owing to the enormous scope of this development scheme, and the expenditure and time it involves, construction will be effected by stages as follows:—

(i) the Bielogorevsk Dam and power plant which can be set up in two or even three steps, according to the power requirements of the Ural industrial centres (Magnitogorsk), up to the ultimate installed capacity of 5·6 MkW, generating 34,000 MkWh p.a.

(ii) the Turgai Gate canal which can also be constructed in several steps according to the power requirements and initial irrigation needs. This project provides for a canal with an initial flow capacity of 1,000 m^3/sec., so as not to hamper generation at Bielogorevsk. Installed capacity of power station: 64,000 kW for an annual output of 600,000 kWh.

(iii) the Pozkmamensk Dam and power plant, whose storage reservoir will permit to divert by gravity to the Ob waters from the Yenissei through the Koss and Kethsk basins without affecting the output of the Bielogorevsk plant. The volume of flow towards Lake Aral and the Caspian Sea will thus be considerably increased. Two power stations are projected: one, on the river, with an installed capacity of 750,000 kW (4,700 MkWh p.a.), the other, drawing its water from the Bielogorevsk reservoir with a 35 m-head, with a capacity of 2·6 MkW generating 20,0000 MkWh p.a.

The following table gives the balance of the waters of the Ob-Yenissei system as planned by Davydov:

Yearly average available:—			
Ob, at Bielogorevsk ...	10,000	m^3/sec. = 315,000	Mm^3.
Yenissei	9,400	„ = 295,000	„
Total ...	19,400	m^3/sec. = 611,000	Mm^3.
Yearly volume utilised:—			
Bielogorevsk Plant ...	8,500	m^3/sec. = 268,000	Mm^3.
Diverted to South ...	10,000	„ = 315,000	„
Evaporation and seepage losses	900	„ = 28,000	„
Total ...	19,400	m^3/sec. = 611,000	Mm^3.

The aggregate installed capacity of the seven power plants contemplated will be 12·9 MkW for a total output of 83,000 MkWh.

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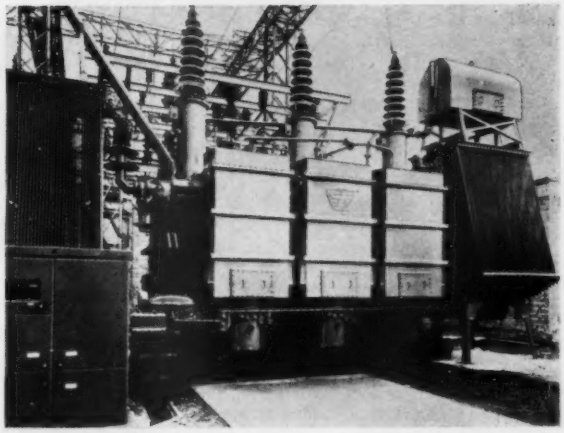

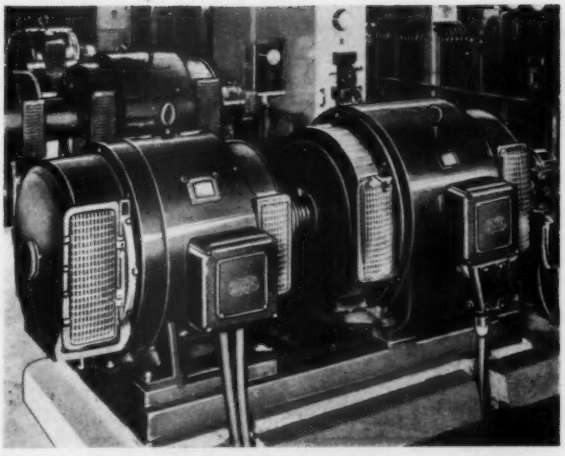

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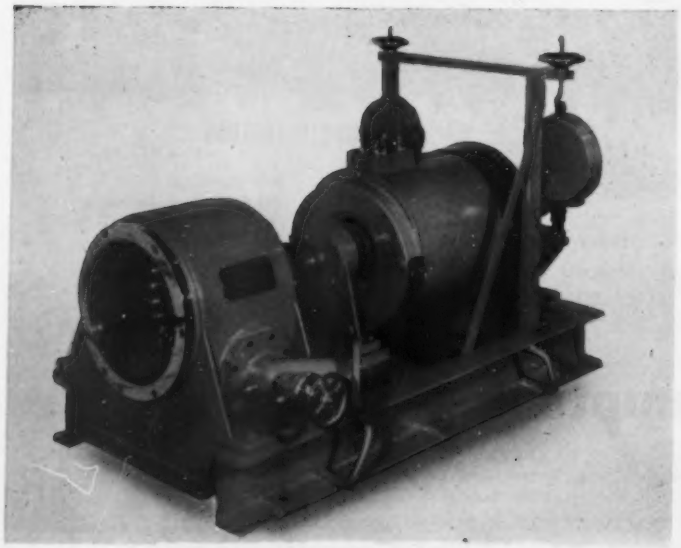

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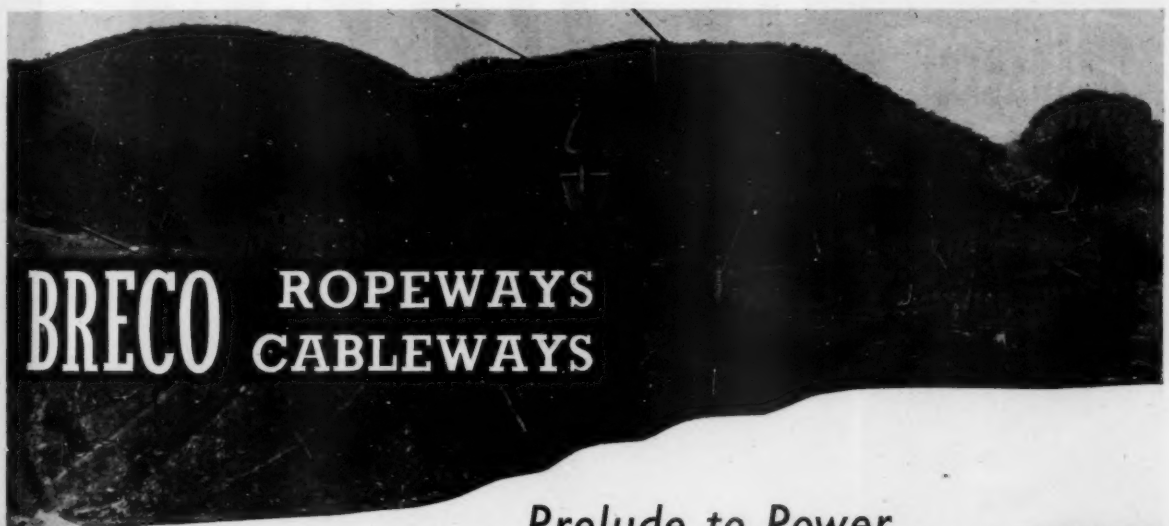

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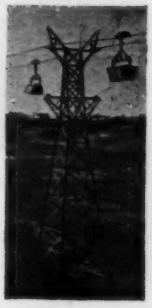

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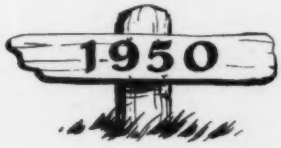

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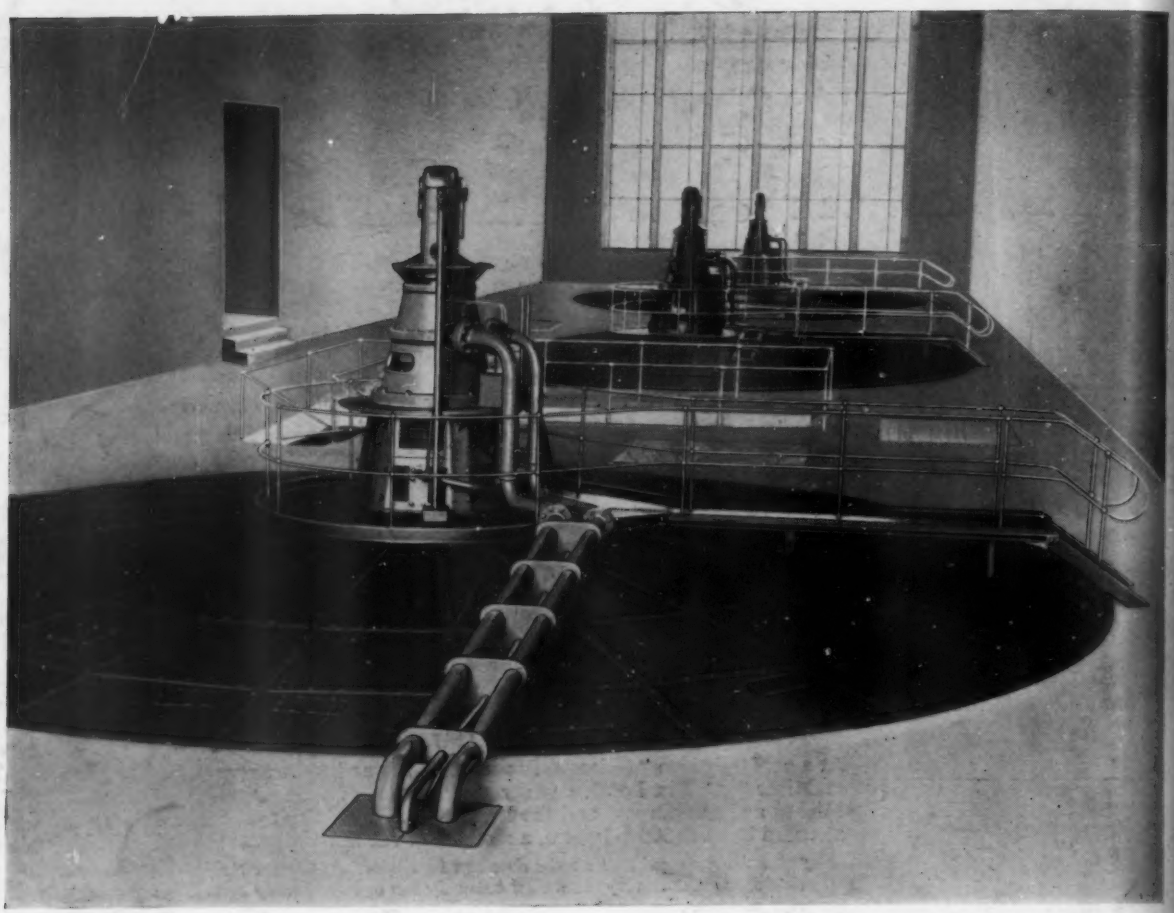

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